Volume 39 • JUNE, 1958 • No. 6

# *Archives of* PHYSICAL MEDICINE *and* REHABILITATION

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Published monthly at Chicago, Illinois, by the American Congress of Physical Medicine and Rehabilitation. Entered as Second Class Matter at the Post Office at Chicago, Illinois.


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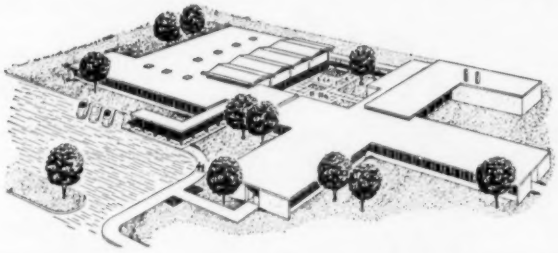

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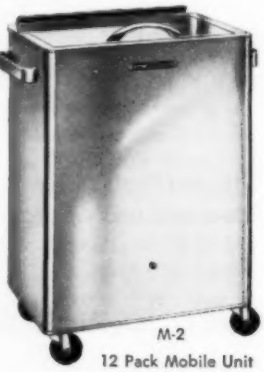

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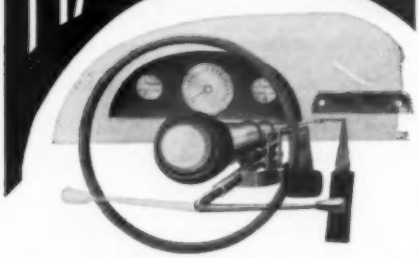

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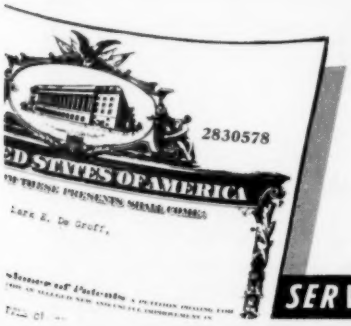


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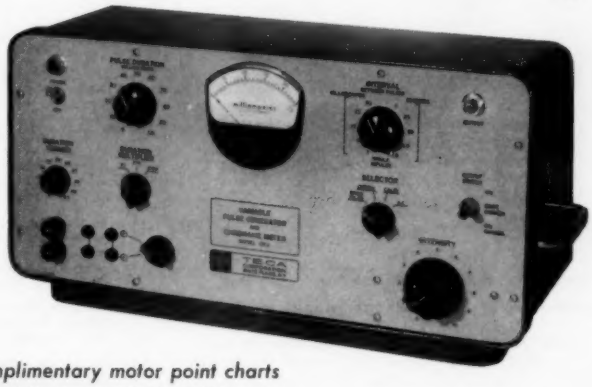

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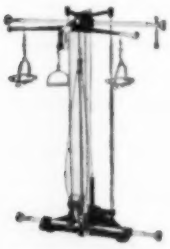

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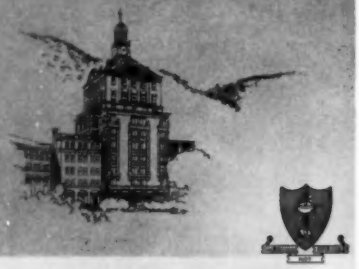

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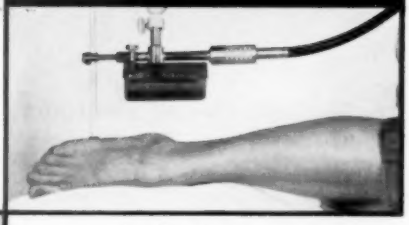

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# Some Factors Influencing the Temperature Distribution in Thighs Exposed to Ultrasound

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● Thigh specimens were exposed to a uniform ultrasound field under well-controlled conditions. The temperature distribution was measured along the axis of the sound beam and the heating pattern studied with special reference to the occurrence of the selective rise of temperature in certain tissues. The factors determining the temperature elevation in the specimen such as absorption and interface reflection of ultrasound, the specific heat and heat conductivity of tissues, were analyzed and their significance for the resulting temperature distribution discussed. Also the temperature gradient in the thigh as it occurs in man and its influence on the rise of temperature resulting from exposure to ultrasound was investigated.

This experimental study was undertaken in the hope of learning more about the factors which influence the temperature distribution in tissues exposed to ultrasound. A better understanding of the heating pattern of ultrasonic energy seemed to be desirable because the results of experimental and clinical investigations suggested that ultrasound is not only an efficient deep heating agent, but also produces, to a certain extent, specific reactions.[1-5] This specificity of the biologic reactions to ultrasound was partially due to a selective rise of temperature in certain areas in the tissues exposed to ultrasound. The specificity of the reactions to ultrasound also may be partially due to the nonthermal reactions occurring in the sound field.[5-9]

It was assumed that the selective rise of temperature in certain areas of the body exposed to ultrasound occurred as a result of differences in the coefficient of absorption of different tissues. It was found that some tissues, such as bone, absorb much more ultrasonic energy than others.[10-13] The assumption that a selective rise of temperature occurred in the bone seemed to be confirmed by the experimental investigations in which a marked rise of temperature was found in this tissue.[14-17] However, these studies were not undertaken primarily with the purpose of investigating the distribution of temperature produced in tissue by ultrasound. The tissues were not exposed to an ultrasonic field of uniform intensity, nor were specimens studied comparable in size and composition to the tissues of a human limb. Therefore, the evidence for a selective rise of temperature in bone is not conclusive.

Other areas, such as peripheral nerves,[2, 18] myofascial interfaces,[19] and tendons, were selectively heated when exposed to ultrasound. The mechanism of this selective rise of temperature in these areas is not known. Reflection, scattering, and also the development of shear waves have been discussed as possible sources of the comparatively high attenuation of ultrasonic energy in these areas.

Not only has an attempt been made to utilize this specific distribution of temperature therapeutically,[5, 20, 21] but it also has been speculated whether it would be possible to destroy bone tumors, such as osteogenic sarcoma, by using ultrasound. It has been hoped that the tumor could be destroyed directly as a result of the selective rise of temperature in the bone,[22] or that the selective rise of temperature in the bone would sensitize the tumors to subsequent x-ray radiation, and thus, bone tumors which were resistant to x-ray therapy might be rendered treatable. It was found that in experimental animals 50 per cent of the x-ray dose could be saved by previous application of ultrasound without changing the growth inhibition of the tumor.[23, 24] The specificity of these effects on the tumor depended solely on

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Read at the Thirty-fifth Annual Session of the American Congress of Physical Medicine and Rehabilitation, Los Angeles, September 12, 1957.

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This work was supported by a grant from the Department of Health, Education and Welfare, Public Health Service, National Institutes of Health.

the selective rise of temperature in the bone.

In conclusion, it seemed to be of interest to study in detail the distribution of temperature in tissues exposed to ultrasound and the factors which influence this distribution of temperature in a limb exposed to a uniform ultrasonic field.

The purpose of the study was to detect the location of the greatest temperature elevation, because the peak temperature in this area would determine the upper limit of the amount of ultrasonic energy which could be applied to the limb without tissue damage, in the process of obtaining a selective rise of temperature for therapeutic purposes in another area. In particular, an attempt was made to determine whether bone represented one of the areas of the greatest rise of temperature; however, no effort was made in this investigation to measure or analyze the selective rise of temperature at interfaces.

### Methods and Instrumentation

An ultrasonic generator operating at a frequency of 1 megacycle per second was used for this investigation.* The radiating surface of the sound applicator was 12 sq. cm. The generator operated with a full wave rectification and thus without modulation of the CW ultrasonic output. The total output was measured with a sound pressure balance. The distribution of ultrasonic intensity within the field in front of the applicator was determined with a sensitized thermocouple probe mounted on a scanning device, which permitted the probe to be moved smoothly and accurately through the entire ultrasonic field. At the same time it permitted the determination of the exact position of the sensitized tip of the probe within the ultrasonic field. Water degassed by boiling was used as a coupling medium. The water temperature was kept constant within the limit of $\pm$ 0.1 degree C. All the ultrasonic exposures were made in a 25-gallon aquarium. The wall of the aquarium opposite the ultrasound applicator was covered with absorbing sponge.

Temperature measurements within the thigh specimen were made with copper-constantan thermocouples which were inserted into the tips of spinal needles mounted on the scanning device. This permitted precise localization of the thermocouple in the ultrasonic field and within the specimen.

The absorption of ultrasound was measured with an ultrasound transmission test set.[11, 13, 16] A sample of tissue was inserted between the transducer and the receiver of this set. Degassed water at constant temperature was used as a coupling medium. The transmission test set was constructed to operate at frequencies between 1 and 3 megacycles per second. All measurements were made at 1 megacycle per second. The radiating surfaces of the transducer and receiver were 4 sq. cm. The ultrasonic output was pulsed with peak intensities of 0.25 watts per square centimeter and pulse duration of 30 milliseconds. The attenuated ultrasonic signal was picked up by the receiver and suitably amplified in order to make it visible on the oscilloscope screen of the apparatus. A step attenuator incorporated into the circuit allowed the operator to compensate for attenuation in steps from 1 to 81 decibels. A gain adjustment allowed the increase of the sensitivity of the apparatus down to 0.25 decibels.

The amount of ultrasonic energy reflected at the surface of the specimen was also determined with the ultrasound transmission set. The attenuation of ultrasound in samples of various thicknesses was plotted against the thickness of the sample. The slope of this curve permitted the determination of the attenuation in decibels per centimeter. The point where the plotted line crossed the ordinate showed the amount of ultrasonic energy reflected at the surface of the specimen.

The sound velocity within the tissues was measured by suitably amplifying the ultrasound signal picked up by the receiver demonstrating the signal on the oscilloscope screen. When the specimen was inserted, a phase shift occurred which

*The generator, Model 2A, and the sound-pressure balance were supplied for this study by the courtesy of the Dallons Laboratories, Inc., Los Angeles, California.

was due to the difference between sound velocities in the specimen and in the water. This phase shift was compensated for by adjusting the location of the receiving transducer with a micrometer. The velocity was calculated from the following formula:

$$V_1 = \frac{X}{D + X} V_W \text{, where:}$$

$V_1$ = velocity of ultrasound in specimen in m./sec.
$V_W$ = velocity of ultrasound in water in m./sec.
$D$ = sample thickness in mm.
$X$ = distance in mm. of water path added to or subtracted from the original path.

The reflection of the ultrasound waves at interfaces between two different media was not only determined experimentally as described above, but also was calculated using the measurements of density of, and sound velocities in, the various tissues. It was assumed that a plane ultrasonic wave was incident perpendicularly at the interface between two infinite media. This calculation gives only an estimate of the actual reflected energy. The following formula was used for these calculations:

$$R = \left(\frac{D_1V_1 - D_2V_2}{D_1V_1 + D_2V_2}\right)^2 \text{, where:}$$

$R$ = ratio of reflected energy to incident energy
$D_1$ = density of tissue1 in gm./cc.
$D_2$ = density of tissue2 in gm./cc.
$V_1$ = velocity in tissue1 in m./sec.
$V_2$ = velocity in tissue2 in m./sec.

The measurements of the specific heat of the various tissues were made in a Dewar calorimeter. The thermal conductivity was determined with the usual laboratory technics.

Thighs of freshly slaughtered pigs were used as specimens after a brief period of refrigeration (less than 12 hours). This specimen was selected because the structure of pig skin as well as the proportion of fat, muscle, and bone in the mid-thigh of the pig resembles that of the human thigh. Random measurements of the cross sections at mid-thigh level of five human cadavers were compared with the cross section of pig thighs which were used in this study. The average diameter of the femur at the pig thigh cross section was 3.2 cm., as compared with 3.2 cm. diameter of the human femur. The diameter of the total cross section of the pig thigh was 20.6 cm., while that of the human thigh was 21.2 cm.

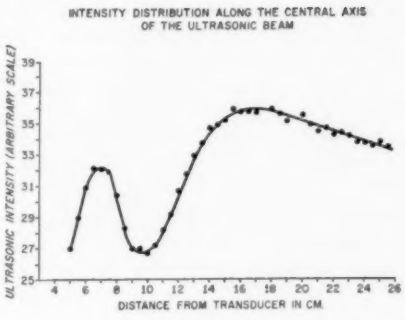



Fig. 1

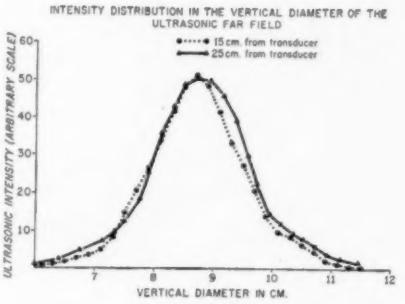



Fig. 2

## Experimental Study of Temperature Distribution

The first series of experiments was undertaken to insure that the specimen was positioned in the ultrasonic field where the intensity was uniform. The distribution of ultrasonic intensity along the axis of the sound beam was measured (fig. 1), and the intensity distribution along vertical and horizontal diameters of the ultrasonic field was determined at distances of 15 and 25 cm. from the applicator. A set of determinations of the vertical intensity distribution at 15 and 25 cm. distance from the transducer is shown in figure 2. From these measurements, it became apparent that the distribution of the ultrasonic intensity at distances of 15 to 25 cm. from the transducer was rather uniform. In this

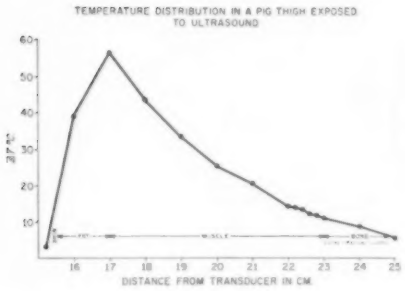



Fig. 3

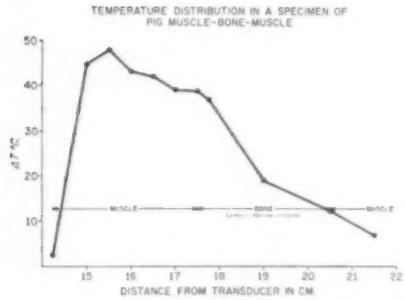



Fig. 4

area, the so-called "far field," the intensity change along the central axis of the sound beam was less than 10 per cent. All of the following experiments were made with the specimens inserted in this area.

In the next series of experiments, six pig mid-thigh cross sections, measuring approximately 15 cm. in height, were inserted in the ultrasonic far field and exposed to a total output of 14 watts. The temperature distribution within the specimen was measured with the thermocouple probe along the central axis of the ultrasonic beam. Each measurement was repeated five times. Results of a typical temperature distribution curve in the thigh are shown in figure 3.

It was found that the highest temperature peak occurred within the subcutaneous fat or close to the fat-muscle interface. The decline of the temperature distribution curve closely resembled an exponential curve. Only a slight irregularity was found in the vicinity of the bone. No selective rise of temperature at the periosteum or within the bone could be observed.

The next series of experiments was undertaken in order to determine whether the temperature peak in the subcutaneous fat was the result of a selective rise of temperature in the fat or would also occur in a uniform tissue covering the bone. In addition, this permitted a study of the temperature distribution in front of the bone if the overlying soft tissue layer was comparatively thin.

In this series of experiments, seven thigh specimens were exposed to ultrasound in the far field after the subcutaneous fat had been removed, so that the thickness of the muscle layer covering the bone was approximately 3 to 4 cm. A typical temperature distribution curve in the specimen exposed to ultrasound under these conditions is given in figure 4. Again a temperature peak was noted in the superficial portion of the specimen. It seemed that the temperature drop in front of the bone was less pronounced than in the other specimens, and at times there was a slight, but not significant, rise of temperature close to the bone. The temperature then dropped more markedly within the bone and behind the bone. In other words, the findings were essentially the same as in the previous whole cross sections exposed to ultrasound, with the exception that the temperature decline close to the bone flattened somewhat if the bone were located closer to the surface of the specimen.

In the following series of experiments, six specimens consisting of the subcutaneous fat with muscle in front of and behind it were exposed to ultrasound; that is, a muscle-fat-muscle layer was used. We hoped this would clarify whether or not a selective rise of temperature occurred in the subcutaneous fat. The previous experiments were inconclusive since a peak temperature occurred in the superficial layers of the tissues regardless of the type of tissues exposed. Figure 5 demonstrates a representative set of determinations. The temperature peak was found in the muscle as expected; however, it appeared that the decline of the temperature distribution curve within the fat was less pronounced than in the muscle layer.

### Discussion of Experimental Results

The previously described experiments demonstrated that ultrasound, if applied to a thigh specimen, produced a temperature peak in the superficial tissue layers, regardless of the type of tissue upon which the sound beam was incident. The temperature decline which occurred with increasing depth of penetration was modified by the type of tissue traversed by the ultrasonic beam. If the bone were closer to the surface, it seemed that the decline of the temperature distribution curves was retarded and leveled off in the muscle tissue close to the bone, and then dropped in and behind the bone. The most unexpected finding was the absence of a selective rise of temperature at the periosteum or within the bone. The temperature distribution curves were only slightly disturbed by the presence of the bone. If subcutaneous fat was exposed between two muscle layers, it was observed that the decline of the temperature distribution curves was less within the fat than within the muscle.

The fact that a temperature peak occurred in the superficial tissue layers could easily be explained on the basis that the ultrasonic intensity within a uniform medium would decrease exponentially as a result of absorption. Since the temperature of the water surrounding the sample was kept constant, the temperature loss could be expected to be greatest at the surface of the specimen. Therefore, it could be anticipated that the result of these two factors was a temperature peak within the superficial layers of the tissues.

The explanation of the other findings was more difficult and made necessary a more detailed study of those factors which influence the rise of temperature in the tissues of a thigh exposed to ultrasound. The following factors were considered: First, the coefficient of absorption of the tissue; second, the amount of ultrasound reflected at the surface of the tissue; third, the specific heat of the tissues; and fourth, the heat conductivity of the tissues.

As the absorption increases, one would anticipate a higher temperature rise. However, as the reflection increases, less ultrasonic energy is available for heating the tissues; therefore, one would expect a decrease in the temperature rise. For tissues with high specific heat, the temperature rise would be less than with those with low specific heats, where they have similar ultrasonic absorption coefficients. Also in those tissues with greater heat conductivity, the temperature rise will be less, since the heat is conducted away more rapidly. Other physical and physiologic factors also influence the temperature distribution in the tissues; however, they are not considered in this study.

It was known from the literature that bony tissues absorbed much more ultrasound than the overlying muscle.[10-13, 16] The comparatively high absorption of ultrasound in bone was used as an explanation for experimental findings of a marked rise of temperature at and in the bone in several investigations; however, as mentioned, their purpose was not primarily to study the possible selective rise of temperature in bone. Also, these experiments were conducted in the near field or in small animals where reliable information on the selectivity of the rise of temperature in the bone could not be obtained.[2, 14-17] In spite of this, it seemed to be necessary that the absorption of ultrasonic energy in bone in our specimen should be determined so that comparison could be made with the high values reported in the literature.

### Measurements of Ultrasound Absorption, Reflection, Specific Heat, and Thermal Conductivity

The difficulties in measuring the exact attenuation of ultrasound in bone have been discussed by Dussik and were encountered in this study.[11, 13] The result of a measurement of ultrasonic attenuation in bone is given in figure 6. The value was obtained by subtracting the loss of ultrasonic energy due to reflection from the total attenuation. The values for attenuation in bone are given in table 1 and are in agreement with those in the literature. Hueter and Bolt[16] found an attenuation in the human skull of 10 db./cm., including reflection, and Dussik[11, 13] found that attenuation by the

patella and the femur of the human was 7.1 db./cm., excluding reflection, and the gross average of cow bone was 12.5 db./cm.

Next, we studied absorption of ultrasound in the muscle and the subcutaneous fat. It was found that very little reflection occurred at the surface of the muscle or the subcutaneous fat (figs. 7 and 8). The results of measurements in many samples are shown in table 1. All our determinations in muscle were made with the sound beam perpendicular to the fibers. Again it was found that the ultrasonic absorption in the muscle of our specimen was essentially the same as that described in the literature.[12, 26] Dussik found that attenuation in human muscle was 0.7 db./cm.[11, 13]

The attenuation observed in fat was approximately three times greater than that reported in the literature. Dussik,[11, 13] for example, found an attenuation of 0.6 db./cm. This discrepancy could be due to dehydration as a result of refrigeration, or due to the fact that pig fat varies considerably from specimen to specimen.

In summary, we confirmed in our specimen the results reported in the literature. We found that the bone in the examined specimens absorbed ten and a half times more ultrasonic energy than the overlying muscle tissue. This suggests that other factors must explain the absence of a selective rise of temperature in the bone in this study.

Next, the amount of reflection at the tissue interfaces was measured. An estimation of the order of magnitude of reflection which might occur at the interface between muscle and bone could be made from our measurements, since the acoustic impedance of water approximates that of muscle. Another estimate of the reflection occurring between the muscle and the bone, or between the fat and muscle, could be made by determining their respective densities and sound velocities, and then calculating

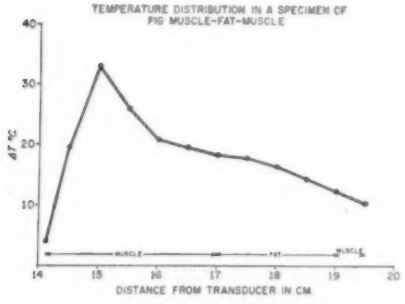
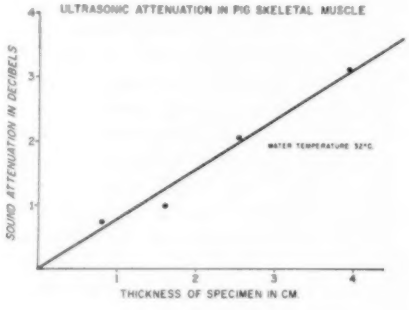



Fig. 5

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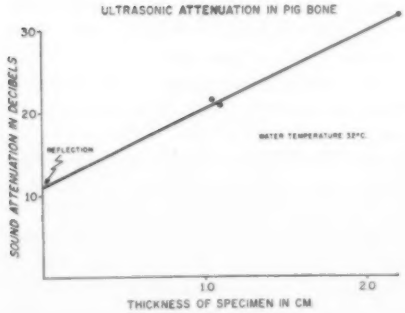


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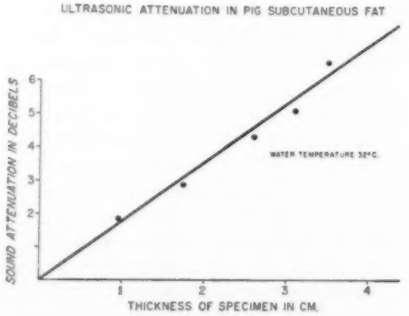


Fig. 8

the reflection. The results of these determinations are given in tables 2 and 3.

Based on these measurements, the reflection at the interface was calculated as previously described, assuming the angle of incidence of the ultrasonic beam to be 90 degrees and the dimensions of the tissues to be infinitely large. The amount of ultrasonic energy reflected at these interfaces is summarized in table 4.

A satisfactory agreement was noted between the measured amount of reflection and that calculated from the mismatch of acoustic impedance between the two media. It should be noted that both determinations of the reflection are minimal estimates, since in one case the reflection was measured experimentally with the sound beam incident on a plane surface at an angle of 90 degrees. In the other case this condition was assumed as a basis for the calculations. Actually, the bone is round, and much of the energy is incident at a much smaller angle than 90 degrees. Therefore, the amount of reflection which can be expected will be greater than that estimated or measured in this manner.

The marked reflection of ultrasonic energy at the bone surface would tend to minimize the heating effect in the bone which otherwise could be expected as a result of the high coefficient of absorption. At the same time, it was also observed that if the overlying soft tissue layer is comparatively thin, as in some of our experiments, the reflection occurring at the bone would tend to increase the amount of ultrasonic energy available to heat the soft tissues in front of the bone.

The specific heat of the tissues was studied, and results of the measurements are given in table 5. They are, with the exception of the fat, in agreement with those published in the literature.[27, 28] The low value of the specific heat of bone, together with the high absorption in that tissue, should tend to facilitate the selective rise of temperature in the bone. Also, the specific heat of the subcutaneous fat being lower than that of muscle would tend to produce a selective rise of temperature in the fat.

**Table 1: Ultrasonic Attenuation in Pig Tissues**

| Tissue | Number of Samples | Attenuation in Db./Cm. | Standard Deviation |
|---|---|---|---|
| Whole bone ... | 13 | 8.4 | ± 1.2 |
| Skeletal muscle ..... | 30 | 0.8 | ± 0.1 |
| Subcutaneous fat ..... | 28 | 1.8 | ± 0.1 |

**Table 2: The Densities of Pig Fat, Muscle, and Bone**

| Tissue | Number of Samples | Density in Gm./Cc. | Standard Deviation |
|---|---|---|---|
| Subcutaneous fat ..... | 8 | 0.937 | ± 0.0046 |
| Skeletal muscle ..... | 8 | 1.07 | ± 0.008 |
| Cortical bone .. | 6 | 1.79 | ± 0.008 |
| Cancellous bone ..... | 5 | 1.25 | ± 0.035 |
| Bone marrow .. | 1 | 0.93 | —— |

**Table 3: Ultrasonic Velocity in Pig Tissues**

| Tissue | Number of Samples | Velocity in M./Sec. | Standard Deviation |
|---|---|---|---|
| Whole bone ... | 1 | 2,814 | —— |
| Cortical bone .. | 3 | 2,941 | ± 614 |
| Cancellous bone ..... | 5 | 2,407 | ± 554 |
| Skeletal muscle ..... | 9 | 1,558 | ± 30 |
| Subcutaneous fat ..... | 12 | 1,454 | ± 10 |

**Table 4: Experimental and Calculated Reflection of Ultrasonic Energy at Tissue Interfaces**

| Interface | Observed Reflection % of Incident Energy | Calculated Reflection % of Incident Energy |
|---|---|---|
| Water-fat (pig) ..... | 0 | 0.2 |
| Water-muscle (pig) ..... | 0 | 0.3 |
| Fat-muscle (pig) ..... | — | 1.1 |
| Water-bone (pig) ..... | 30 | 30 |
| Muscle-bone (pig) ..... | — | 26.8 |

**Table 5: Specific Heat of Pig Fat, Muscle, and Bone**

| Tissue | Number of Samples | Specific Heat in Cal./Gm./°C. | Standard Deviation |
|---|---|---|---|
| Subcutaneous fat ..... | 6 | 0.621 | ± 0.015 |
| Skeletal muscle ..... | 6 | 0.750 | ± 0.017 |
| Cortical bone .. | 6 | 0.323 | ± 0.025 |
| Cancellous bone ..... | 3 | 0.504 | ± 0.015 |
| Bone marrow .. | 4 | 0.655 | ± 0.008 |

Table 6: Thermal Conductivity of Pig Fat, Muscle, and Bone

| Tissue | Number of Samples | Thermal Conductivity in Cal. x Cm. / Cm.² x Sec. x °C. |
|---|---|---|
| Subcutaneous fat ..... | 2 | 0.0065<br>0.00055 |
| Skeletal muscle ..... | 2 | 0.0012<br>0.00124 |
| Whole bone ..... | 1 | 0.0035 |

Finally, the thermal conductivity of the various tissues was studied. The results are shown in table 6. It was found that the thermal conductivity of bone is approximately three times greater than that of muscle. These differences in the thermal conductivity would tend to minimize the expected temperature rise in the bone. The low thermal conductivity of fat would make the rise of temperature resulting from the ultrasonic absorption more pronounced.

In summary, these experiments showed, as expected from the literature, that bone absorbs much more ultrasound than the overlying soft tissues; however, the expected selective rise of temperature at bone would be minimized as a result of the reflection which occurred at the bone-muscle interface. This decreases the amount of ultrasonic energy penetrating the bone, and adds to the amount of ultrasonic energy absorbed in the soft tissues in front of the bone. At the same time the higher conductivity of the bone tends to dissipate the heat developed in the bone more rapidly than in the soft tissue surrounding the bone. On the other hand, the specific heat of bone is lower than that of subcutaneous tissues and would tend to facilitate rise of temperature in the bone resulting from the absorption of ultrasonic energy. Whether or not other factors are involved in preventing the selective rise of temperature in the bone remains to be investigated.

The suggestion of a selective rise of temperature in the subcutaneous fat, which was found in the temperature distribution studies in tissues exposed to ultrasound, would at least partially be explained on the basis of the unusually high absorption in our specimen in this type of tissue, and also by the fact that the specific heat of fat is slightly lower than that of muscle, and that its thermal conductivity is approximately half that of muscle.

## Experimental Change of the Heating Pattern Produced by Ultrasound

Since it was found that a temperature peak occurred in the superficial tissue layers where therapeutically it might be least desirable, it seemed worthwhile to study the peak location and the possibility of altering it in a human being treated with ultrasound.

In the previous experiments the whole specimen was brought into temperature equilibrium with the surrounding water bath before the exposure to ultrasound. Thus, there was no temperature gradient, a situation exactly opposite to therapeutic conditions where a marked temperature gradient exists in the thigh from the skin to the bone. This temperature gradient was measured in two volunteers, and is demonstrated in figure 9. We tried to duplicate this temperature gradient experimentally in the following manner: First, the specimen was warmed to a temperature of 37 C. and kept at this temperature while cooler (27 C.) degassed water was put into the aquarium as a coupling medium. The temperature gradient produced closely resembled that measured in a human thigh (fig. 10). Then ultrasound (10 watts total output) was applied to the specimen and the temperature distribution was measured, after 30 seconds, with six thermocouple probes spaced 0.5 cm. apart inserted along the central axis of the beam. It was found that the temperature peak under these conditions was located deeper than 2.5 cm. from the skin. However, if the same specimen were exposed to ultrasound with the specimen and water bath in temperature equilibrium before the exposure to ultrasound, the temperature peak was found very close to the surface (fig. 10).

In conclusion, it can be assumed from these experiments that the highest temperature obtained in a human thigh exposed to ultrasound under therapeutic conditions is found deeper inside the

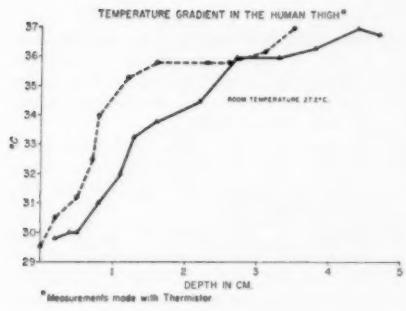


Fig. 9

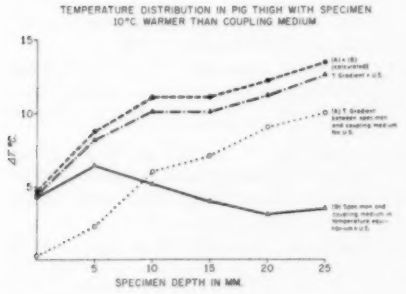


Fig. 10

tissues than in our specimens. It also can be assumed that the cooler the surface of the applicator or the coupling medium, the deeper inside the tissues the temperature peak will be found. The explanation for this is that the original temperature gradient in the living specimen is superimposed on that created by the ultrasound. As a matter of fact, if the temperature gradient produced by ultrasound is added to the temperature gradient present in the specimen before ultrasonic exposure, a curve is obtained which is almost identical to the experimentally determined curve; that is, exposing the specimen with the artificially created temperature gradient to ultrasound (fig. 10). Naturally other physiologic factors, such as alterations of the blood flow resulting from the exposure to ultrasound, will also influence the final temperature distribution in a human limb treated with ultrasound.

## Summary and Conclusions

No selective rise of temperature was found in the bone of a pig thigh specimen exposed to ultrasound. The absence of the selective rise of temperature in the bone was surprising because it occurred in spite of a greater attenuation of ultrasonic energy in bone than in the overlying soft tissues, and in spite of the comparatively low specific heat of the bone. This unexpected result could be explained partially on the basis that a large share of the ultrasonic energy was reflected at the surface of the bone, and thus decreased the amount of energy penetrating the bone, and increased at the same time the amount of ultrasonic energy converted into heat in the overlying soft tissue structures. This finding also was perhaps partially explained as a result of the comparatively high thermal conductivity of bone.

A suggestive selective rise of temperature in subcutaneous fat was partially explained on the basis of a higher absorption of ultrasonic energy in fat than in the underlying muscle. However, this finding seems to be specific for our type of specimen, and generalization is not warranted, since lower absorption values for subcutaneous fat were reported in the literature. A slight selective rise of temperature in subcutaneous fat might also be explained by the fact that the specific heat of subcutaneous fat is slightly lower than that of the underlying muscle, and that its thermal conductivity is approximately half that of muscle.

Finally, the highest peak of the temperature distribution was found in the superficial layers of the tissues exposed to ultrasound. The location of this peak of temperature was also influenced by the original temperature gradient within the specimen. When this gradient resembled that found in the thighs of human volunteers, the peak of the temperature distribution after ultrasonic exposure was found in the deeper layers of the tissues. This experiment suggests that the temperature peak can be transferred into deeper portions of the treated part if the applicator surface or the surrounding coupling medium is cooled during ultrasonic application.

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# Effects of Breathing Exercises on Pulmonary Emphysema

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● According to studies done to date, breathing exercises seem to have little objective value in emphysema but their subjective value should not be dismissed lightly. No laboratory methods are yet devised for measuring all factors that may be improved by these exercises. The main stress should be on the importance of living within the physical bounds imposed by the disease and the use of these exercises in recovery from dyspnea when these bounds are exceeded.

Breathing exercises are often used for treatment of pulmonary emphysema and many reports have appeared concerning their benefits.[1-5] However, there have been very few objective studies of their value using laboratory methods. Evidence is accumulating that these exercises alter nothing that can be measured in the laboratory. The purpose of this paper is to discuss the pathologic physiology of emphysema and then to consider the possible effects of breathing exercises on the disease by comparing five such laboratory studies.

Hypertrophic pulmonary emphysema is defined as a disease process of the lungs marked by diffuse bronchial obstruction, by changes in alveolar walls producing enlarged air sacs, by diffuse changes in the interstitial lung tissue, and by narrowing and thickening in the walls of the pulmonary blood vessels with a decrease in the capillary bed. The diffuse changes in the interstitial tissue consist largely of loss of elastic tissue so that the contractile force needed to deflate the lungs is lost. This describes the essential pathologic anatomy of pulmonary emphysema.

## Etiological Factors

*Infection.* Chronic pulmonary infection produces fibrosis and destruction of lung and causes loss of lung elasticity, bronchial obstruction, and cough.

*Bronchial Obstruction.* Bronchial obstruction is produced by bronchospasm, increased bronchial secretions, bronchial infection, and alteration in the normal dynamics of air flow. It probably reflexly causes vascular spasm and so reduces blood supply to the lungs.

*Cough.* The abnormality of dynamics of air flow produced by increased intrathoracic pressure in the cough of chronic lung disorders contributes to alveolar distension and air trapping.[6]

*Hypoxia.* The bronchiolar and pulmonary arteries are often obstructed in emphysema. Because of poor blood supply and low oxygen saturation of the blood, oxygen starvation of the pulmonary tissues and other tissues — such as nervous and muscle tissue — contributes to deterioration in these patients.

## Pathologic Physiology

*Ventilatory Aspects.* The striking change in the lung volumes in the emphysematous patient is the increase in the functional residual capacity and the residual volume with a reduction in all other volumes that make up the vital capacity of the lung (fig. 1). Normally expiration depends almost entirely on the elastic recoil of the lung. As this property is lost air tends to remain in the alveoli and produce these volume changes.

Reduction in the velocity of expiratory outflow is another characteristic of emphysema. This change is particularly noted in the maximum breathing capacity, where the amount of air moved in and out of the lung per minute is greatly reduced.

A third typical feature is the reduction of mixing efficiency; gas exchange is much better in some parts of the lung than in others. The mechanisms producing these changes were very clearly explained by some extensive studies of intrathoracic and intrapulmonary pressure relationships by Fry and his coworkers.[7]

When the kinetic forces involved in ventilation of the lung are considered,

This paper received the 1957 Annual Essay Award of the American Congress of Physical Medicine and Rehabilitation.

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the intrathoracic pressure ($Pt$) in a dynamic state of the lung is equal to the algebraic sum of the pressure ($Pl$) caused by the retractive force of the lung and the pressure difference between the alveoli and oral cavity which is required to produce gas flow along the bronchial tree ($Pp$). This can be expressed mathematically as:

$$Pt = Pl + Pp$$

Figure 2 demonstrates how these pressures act in respiration. In emphysema $Pl$ becomes small and $Pp$ increases during expiration to overcome the increased resistance to air flow. The intrathoracic pressure, therefore, becomes positive much earlier in the expiratory cycle and tends to collapse the bronchiole. In other words, in emphysema where the retractive force of the lung ($Pl$) is exceeded by the pressure drop ($Pp$) needed to produce flow from the alveolus to the cartilage-supported bronchi, a net pressure which produces attenuation of the bronchiole develops and thus slows expiratory air flow.

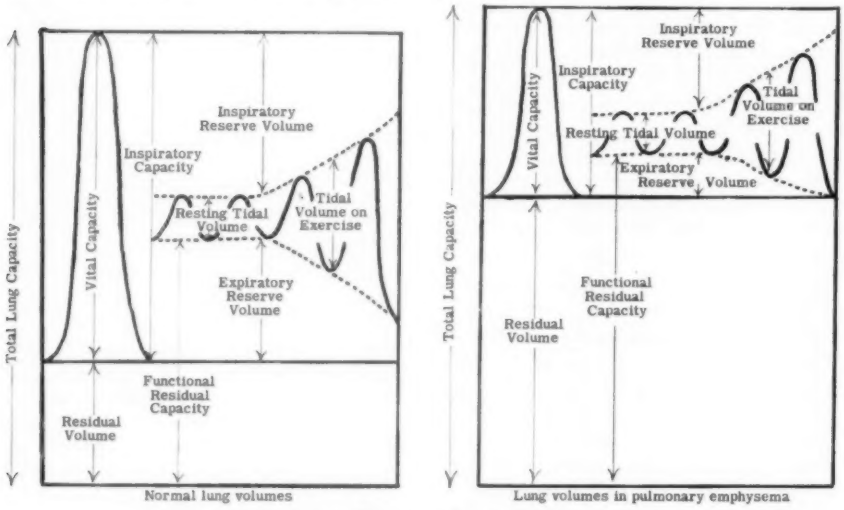


Fig. 1 — Diagram to illustrate relative size of lung volumes.

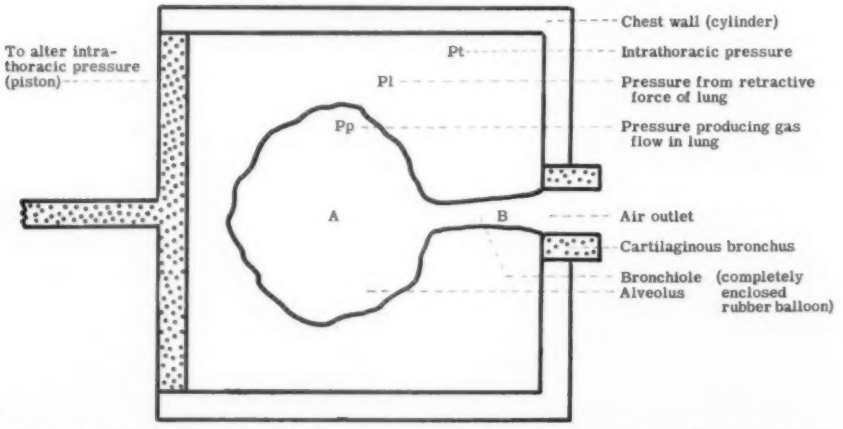


Fig. 2 — The dynamics of air flow in the vicinity of an alveolus illustrated in a model (after Fry et al[7]). On inspiration $Pp$ is negative; on expiration $Pp$ is positive (with respect to the atmosphere). $Pl$ is negative and with the lungs at rest $Pt = Pl$. Pressure in bronchiole at $B$ is atmospheric. During expiration $Pt$ is negative until $Pp$ exceeds $Pl$. $Pt$ then becomes more nearly positive. Now $Pt$ tends to collapse a partially obstructed bronchiole whereas formerly it tended to distend it.

Increased resistance to air flow is also caused by unequal ventilation of various portions of the lung due to unequal loss of elasticity; less elastic portions fill earlier in the inspiratory cycle than do well-preserved ones. Therefore, at a given time there is more rapid air flow in some than in others and a reduced mixing efficiency occurs. Bronchospasm and obstruction of bronchioles by secretions also cause increased resistance.

In normal subjects, to produce a given flow of air more pressure is required when the lungs are less inflated, that is, at lung volumes near residual volume. Hence, in emphysema, to overcome the slowing of respiratory flow, greater lung inflation is needed and attempts to increase ventilation by increased inspiratory efforts are made by all these patients.

When considered in the light of these studies, the problem of pulmonary emphysema is not primarily to increase the vital capacity but to alter the pulmonary dynamics so that, although this diminished flow rate may not be changed, optimum flow can be produced with minimum effort.

*Gas Exchange.* Circulation and diffusion problems in emphysema at the alveolocapillary level have been extensively studied. As it would be hard to argue that the pathologic changes at this level can be altered by breathing exercises, detailed discussion of pathologic physiology here seems unnecessary.

*Mechanical Aspects.* Wade[9] and Campbell[10, 11] have extensively studied the mechanical action of the muscles of respiration.

The following discussion is largely derived from their observations.

During quiet respiration muscle action produces inspiration; elastic recoil produces expiration. The diaphragm is the most important muscle of inspiration; three quarters of the vital capacity is due to its action and only one quarter is due to chest wall movement. Although the resting position of the diaphragm is higher in the chest when a person is supine than it is when he is erect, its total range of movement is approximately the same in both these positions.

In emphysema, as the elasticity of the lung is lost, the diaphragm appears to flatten and lose its normal excursion. However, careful studies have shown that this is due to increased vertical movement and expansion of the chest giving a false fluoroscopic impression.[9, 12] Thus there is close coordination between chest wall and diaphragmatic muscle action; one does not change without a corresponding change in the other.

There is no evidence that the diaphragm is under selective voluntary control. The extent of its movement seems determined only by the depth of respiration.

Wade[9] reports that when patients and physical therapists tried to separate "chest" from "diaphragmatic" breathing, the movement of the diaphragm did not change. The breathing pattern that appears in emphysema is not due to a change in diaphragmatic movement, but to flexion and extension of the dorsal spinal column with perhaps some assistance from the accessory muscles of respiration.

The smooth coordinated movement of the respiratory muscles is often lost in emphysema. For example, a "jump back" motion of the diaphragm on both inspiration and expiration is sometimes seen on fluoroscopy.[13] As the smooth normal expiratory flow of air becomes disturbed, incoordinate movements appear.

Normal subjects can attain very high ventilatory rates without using the sternomastoid muscles and do not seem to use them even on very deep breaths. The excessive use of the sternomastoids in emphysema is a common observation. It appears that they become important only when the respiratory level is elevated, so that ordinary inspiratory muscles are operating at a much reduced mechanical advantage.[12]

The abdominal muscles are the only indisputable muscles of expiration. However, in a resting state, even with the body in an erect posture, there is normally little activity in them. A ventilatory rate of over 40 liters per minute must be reached before action in them appears and then it appears toward the end of expiration, not at the be-

ginning as one might expect if they were under control of the expiratory center. Furthermore, they appear to play little part in natural expiration even when pulmonary ventilation is increased up to 100 liters per minute. Even under these circumstances the intra-abdominal pressure remains remarkably stable. If they aided expiration by helping force up the diaphragm, a large rise in intra-abdominal pressure would be expected.[10]

Untutored patients with emphysema do not tend to use their abdominal muscles for expiration. The pattern of the disease is one of increasing and changing inspiratory action. Some patients, however, do tend to have abdominal muscle contraction at the end of inspiration and ineffective muscle actions may appear.

In summary, the disturbances in muscular action in emphysema consist of fatiguing, inefficient and incoordinated activity as the muscles try to work harder to make up for the loss of lung elasticity. As diaphragm and chest wall motions are closely coordinated, it appears very unlikely that due to muscular action alone part of the lung is inefficiently ventilated, for example, the lung bases.[14] Inefficient ventilation of any part is primarily due to obstruction of expiratory flow.

*Neurogenic Considerations.* The nervous control of respiration is now generally believed to be due to an intrinsic periodic rhythm generated within the medulla, not directly controlled by reflex excitation (the Hering-Breuer reflex) but influenced by the well-known chemical stimuli, and little-known reflex and cortical influences.

The chief complaint of the patient with emphysema is dyspnea, a subjective phenomenon that cannot be measured exactly. Therefore, it should be in disturbed neural mechanisms that an explanation for this disagreeable sensation might be sought, but very little is known about the production of dyspnea. One possibility is that, at a certain point of stimulation of receptors in muscles (chemoreceptors found in skeletal muscle might explain this[15]), impulses are relayed to a higher center to produce the perception of breathing discomfort.[16] The emphysema patient with increased activity of inspiratory muscles may reach this point of overstimulation of muscle receptors earlier than normal and so become dyspneic primarily from this cause.

When breathing reserve reaches 60 to 70 per cent of maximum breathing capacity, dyspnea generally occurs. However, absence of dyspnea has been described in patients whose reserve was only 40 to 50 per cent of their maximum breathing capacity. This suggests either a blunting of sensation in these patients, possibly due to acute anoxia of the central nervous system, or a psychologic adaptation to this uncomfortable state.[8]

From the "visceral brain" in the limbic region of the cortex, where the interplay of emotions and the vegetative functions probably take place, there are many interconnecting pathways to the respiratory center in the medulla. Neurophysiology is not far enough advanced to tell whether any disturbances might occur here in emphysema. At present we can only note that emotional influences play a large part in the degree of respiratory distress in emphysematous patients.

### Five Studies of Emphysema

A summary of the methods used in five studies which evaluated the effects of breathing exercises is presented in table 1. A reference to figure 1 will explain the meaning of various terms used in reference to rest measurements. Although none gave detailed explanations of the exercises used, it can probably be safely assumed that they were basically similar to those originally proposed by the Asthma Research Council.[17] Here the patient is taught to correct the incoordination in his breathing, to make expiration active by contracting the abdominal muscles, and to relax excessive motion of the upper thorax and shoulder girdle. In all studies except those of McNeill and MacKenzie, it was explicitly stated that maximum benefit from all other forms of emphysema therapy was obtained before exercises were started. Any differences in patient selection and methods can be noted in the table.

Results and conclusions of the studies of Becklake and co-workers, Sinclair, and

McNeill and MacKenzie are noted in table 2.

Becklake and her group[18] compared their results from week to week by graphs of individual patients and noted a great fluctuation in the measurement of ventilatory function. The electric stimulations caused no observable improvement over the breathing exercises alone. However, in spite of lack of objective improvement, all but two were subjectively improved after exercise treatment.

These patients were perhaps more handicapped than those in the other studies. Twelve patients had elevated hemoglobin and hematocrits; seven showed right ventricular enlargement on electrocardiography; six had had previous congestive heart failure, and all desaturated their blood oxygen on effort. However, any patients developing infection or any evidence of cardiac failure during the exercise period were immediately excluded from the series.

Sinclair[12] discovered, as did Becklake, that the exercises gave very good subjective benefit but little valuable objective benefit. However, five patients showed definite objective improvement after treatment. There was no clue as to a common factor to account for improvement; all subjects were of widely different ages; there was nothing special about etiology, onset or severity of symptoms.

Diaphragmatic movement apparently increased from 2.7 to 5.8 cm., and movement which had been jerky before treatment became smooth. However, as explained previously, this was due to decreased vertical motion of the thorax. This motion was remarkably reduced after exercise treatment. When allowance was made for this decreased thorax elevation, diaphragmatic excursion was found to average 2.7 cm. per 1,000 ml. of vital capacity. This is very similar to the 2.6 cm. per 1,000 ml. of vital capacity in 10 normal patients examined by Wade.[9]

None of Sinclair's patients had been in cardiac failure nor had any other disease contributed to their disability. Thus perhaps they were better patients for study than Becklake's or Miller's.

Only about two thirds of McNeill and MacKenzie's[19] series of patients had emphysema. However, the measurement of the expiratory flow rate (E.F.R.) was not included in the other series, yet it is probably an excellent simple index of disturbed expiratory function. It is argued that bronchospasm is increased in the sustained effort for measurement of maximum breathing capacity and so the single expiration of the E.F.R. measurement is a better index of actual lung pathology. As shown in the table there is little evidence that E.F.R. is improved by exercises.

The results of Miller's[20] study (table 3) were quite a contrast to those of the previous three. He felt that his study demonstrated that the exercises give unquestionable objective benefit.

These patients were on the average somewhat younger than Becklake's; five had hematocrits over 50 per cent, and less than half desaturated their blood oxygen on exercise. Thus their emphysema does not appear to have reached such an irreversible stage.

A major criticism of their study is that the patients were not rechecked frequently as in the other studies, but only at the beginning and end of a 6- to 8-week period. Other worsening or improving factors may have occurred during this time. As explained elsewhere, his observation of increased diaphragmatic excursion is probably only an illusion.

Campbell and Friend[14] concluded that the exercises did not alter significantly the total capacity of the lungs, or its subdivisions, the method of mixing inspired air in the lungs, or the maximum breathing capacity. Their study is not included in table 2, as numbers of patients improved or unimproved were not specified.

To study the "immediate action" of the exercises they made electromyographic and spirometric recordings with exercise type breathing and then with natural breathing, observations that were lacking in other studies. The immediate effects of the breathing exercises were as follows:

1. Decreased rate and increased depth of breathing.

**Table 1: Methods of the Studies Compared**

| Author | No. of Cases and Ages | Control | Days of Treatment with Exercises | Lung Volume and Ventilatory Studies | Studies of Alveolo-ventilatory Function (Blood Studies) | Studies of Muscle Action | Other Observations |
|---|---|---|---|---|---|---|---|
| Becklake et al (South Africa) | 15 Age 38-75 | 10 had electric stimulation of abdominal and chest wall as well as exercise | 13 to 62 (rechecked with studies each week) | Total lung capacity and its subdivisions. Mixing efficiency (using Helium indicator). Maximum breathing capacity | Per cent $O_2$ saturation at rest, after exercise, after hyperventilation. Alkali reserve | ——— | Subjective responses |
| Sinclair (New Zealand) | 22 Age 32-70 | ——— | 21 to 84 (rechecked repeatedly) | Total lung capacity and its subdivisions. Mixing efficiency (using nitrogen indicator). Maximum breathing capacity. Minute ventilation | Per cent $O_2$ saturation at rest | Maximum diaphragmatic excursion. Vertical motion of chest | Subjective responses |
| McNeill and MacKenzie (England) | 25 Age 9-67 (15 emphysema: 8 had asthma or bronchitis) | 8 had ultraviolet light therapy | 28 to 90 (checked before and after exercise program) | Expiratory flow rate (E.F.R.) in the first ¾-second period of a single forced expiration following full inspiration | ——— | ——— | ——— |
| Miller (United States) | 24 Age 28-64 | ——— | 42 to 56 (checked before and after exercise program) | Total lung capacity and its subdivisions. Maximum breathing capacity. Maximum expiratory pressure. Oxygen removal rate. Liters of ventilation per square meter of body surface per minute at rest and after exercise. | Per cent $O_2$ saturation at rest, after exercise.<br>Tension of $CO_2$ in plasma at rest, after exercise<br>Arterial pH at rest, after exercise | Maximum diaphragmatic excursion | Respiratory rate. Dyspnea after exercise |
| Campbell and Friend (England) | 12 ——— | ——— | 56 to 96 (rechecked repeatedly) | Total lung capacity and its subdivisions. Mixing efficiency (using nitrogen indicator). Maximum breathing capacity. Effective tidal volume | ——— | 7 had electromyographic studies of the sternomastoid and abdominal muscles | Immediate effect of exercises |

**Table 2: Results and Conclusions of Three Studies**

| Study | Improved | Deteriorated | No Change | Conclusions |
|---|---|---|---|---|
| Becklake et al | 2 probably<br>2 possibly | 3 | 8 | Exercises are of no objective value. |
| Sinclair | 7 markedly<br>7 moderately | 0 | 8 | Tests varied toward improvement but too small to be significant physiologically or statistically. |
| McNeill and MacKenzie | 11 (subjects)<br>3 (controls)<br>(ultraviolet light) | 6<br>4 | 0<br>1 | Little evidence of value. E.F.R. is not improved. |

**Table 3: Results of Miller's Study**

| Measurement | After Exercise |
|---|---|
| Ventilatory response (Liters/sq. M./min.) | Unchanged (average)<br>Increased slightly (worst 7 of group) |
| Maximum expiratory pressure | Slight increase |
| Vital capacity | 23% improvement |
| 3-second vital capacity | 26.7% improvement |
| Maximum breathing capacity | 37.7% improvement |
| Blood oxygen saturation (13 patients) | Slight rise |
| Plasma carbon dioxide tension (13 patients) | Slight fall |
| Plasma pH | No change |
| Postexercise dyspnea | Fell from 92 to 70 seconds |
| Diaphragmatic excursion | Average increase of 3 cm. |

2. Increase in effective tidal volume with increase in effective minute volume.
3. Mixing efficiency and functional residual capacity (poorly ventilated space) unaltered.
4. A lowered respiratory level with decreased chest inflation.
5. Prolongation in expiration.
6. Increased activity in the abdominal muscles, particularly the external obliques; little reduction in activity in the sternomastoids.

When trained patients were forced to hyperventilate by rebreathing expired air from a spirometer, they all stopped using their abdominal muscles. However, some made breathless by exertion seemed to recover more rapidly using "exercise breathing" than by natural breathing.

They concluded that the exercises were of some value but that changes noted were mostly those of slow deep breathing in an increasedly expiratory position, and during moderate exertion exercise-type breathing would not supply adequate ventilation.

## Conclusions

These studies seem to have covered fairly adequately many of the physiologic aspects of pulmonary emphysema. Perhaps some of the series should have been larger and the observations made over a longer period. Pulmonary function information on untreated control patients during the periods studied would have been enlightening, particularly in the study of Miller.

The following conclusions seem to be justified in the light of these studies.

Permanent changes in lung volumes, expiratory flow rate or mixing efficiency can not be produced by breathing exercises. The loss of lung elasticity is permanent and cannot be reversed by attempting changes in the externally applied mechanical forces. Miller[20] and Barach[2] suggest that this conclusion is incorrect. However, a brief consideration of the pathologic physiology and the findings in four studies that were better controlled and analyzed than Miller's will support this observation.

There is undoubtedly temporary improvement in the efficiency of ventilation when these exercises are practiced because in slow breathing the compliance of the lungs is greater than in fast breathing. The effective minute volume is increased. Furthermore, an expiration produced by active contraction of the abdominal mus-

cles lowers the end expiratory level of the lungs more than normal. This increases the rate of mixing of inspired air in the lungs as shown by experiments in normal persons.[21]

If this altered pattern of breathing, with expiration as the active phase instead of inspiration, could become involuntary, then perhaps permanent benefits in pulmonary ventilation would occur. None of these authors has suggested that this could happen, although some advocates of the exercises claim to have observed this type of breathing even when the subject was sleeping. Because of the involuntary nature of respiration, especially during increased exercise, it seems very difficult to believe that this can occur. Nevertheless, this type of unnatural respiration seems particularly suitable to recover from the effects of overexertion, and many patients remark that this is the chief benefit that they have observed. It may be that, in the immediate postexercise period, oxygen consumption and carbon dioxide excretion studies would show the value of exercises. Miller's[20] studies would seem to confirm these observations.

It is in the decreased amount of mechanical work required for breathing that patients probably derive their greatest benefit from the exercises. The work of raising the thoracic cage by extension of the spine is much diminished and work efficiency increases as movements are better coordinated. However, it should be emphasized that total diaphragmatic excursion very likely does not increase, and that the raising of intra-abdominal pressure by contraction of the abdominal muscles is so slight that expiratory flow rate is probably improved very little, especially if the bronchiole closing action of raised intrathoracic pressure is considered.

The most striking aspect of breathing exercises is that subjective improvements greatly exceed the improvement in any measurable pulmonary function. Becklake and co-workers[18] dismiss this as mainly psychologic benefit in persons with a hopeless disease who find doctors and physical therapists sincerely interested in their plight. Undoubtedly this is an important factor but it hardly seems to be a complete explanation. The decrease in unprofitable muscular activity possibly reduces the afferent impulses leading to dyspnea. If some emphysematous patients are not as aware of dyspnea as some persons, as has been observed, then it would not take a very startling reduction in muscular effort to make them feel better.

## Summary

Although breathing exercises, according to studies done to date, seem to have little objective value in emphysema, their subjective value should not be lightly dismissed. No laboratory methods are yet devised for measuring all factors that may be improved by these exercises. However, patients should not be given faulty illusions about "diaphragmatic breathing" or about better ventilating the lower part of the chest by exercise; neither should it be suggested that these exercises are going to become "natural" and change the irreversible pulmonary pathology. The main stress should be on the importance of living within the physical bounds imposed by the disease and the use of these exercises in recovery from dyspnea when these bounds are exceeded.

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**NOW . . . *is the time for***

all members of the American Congress of Physical Medicine and Rehabilitation and the American Academy of Physical Medicine and Rehabilitation to mark their calendars for the *new business meeting schedules!*

The Congress has scheduled its first business meeting for 4:00 p.m. and 7:30 p.m. on Tuesday, August 26. The second business meeting will be held on Thursday, August 28 at 4:00 p.m.

The Academy has planned its single business session for 7:00 p.m. on Monday, August 25.

See the Preliminary Program Issue (July, 1958) for complete details.

# Ambulation Problems in Hemiplegia

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and
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● This is a report on 200 cases of hemiplegia resulting from a variety of etiological factors including trauma, cerebral vascular accident including hemorrhage and thrombosis, cerebral embolus and others, which were admitted to the rehabilitation service of The Burke Foundation. A specific analysis of the physical, social, psychological and vocational status of these patients is included as well as the results of rehabilitation treatment. In particular, the paper analyzes those patients who failed to achieve independent ambulation; achieved only partial independence in ambulation, or who required a prolonged period of treatment before a satisfactory degree of ambulation was achieved. Ordinary problems of a general medical nature, associated amputation, fracture or arthritis and paralytic muscular factors are evaluated. However, primary stress is not placed upon these but rather on problems of cerebellar system involvement, ataxia, apraxia, perceptual problems. The specific problems of muscular weakness and spasticity are outlined.

This study was carried out to determine the causes of failure in independent ambulation in a group of hemiplegic patients. Since the return of this function occurs in such a high percentage of patients who do not succumb during the acute phase of the illness, overcoming the particular and specific mechanisms for failure among the others becomes a major objective. We were particularly interested in determining whether factors other than clear-cut defects in neuromuscular function resulting from paresis or spasticity played an important part.

Since they have been mentioned as possible factors, we considered conscious sensory defects, particularly in position sense, cerebellar involvement with ataxic elements, visual perceptual defects, apraxia, and substitute technics for advancing the paretic lower extremity, as they related to balance and righting reflexes in those hemiplegics who failed to walk completely independently.

## Method

We have reviewed 200 consecutive inpatients admitted to the rehabilitation service of The Burke Foundation with cerebral vascular accidents resulting in hemiplegia. No screening was performed prior to admission so that a high percentage of patients with poor rehabilitation potential is included. Initial care in the acute phase was either in a general hospital or at home. Pertinent factors in each case of failure in independent ambulation were evaluated to determine the reason for the failure.

Cases were classified at time of discharge only in terms of ambulation as "success" (completely independent with or without cane or brace), "premature discharge" (insufficient time for recovery or therapy), "unfeasible for rehabilitation" (general medical or mental condition unsatisfactory), "deteriorated" (became acutely ill and therapy discontinued), or "failure." The "failures" in terms of completely independent ambulation were classified as "true failures" if ambulation were safely limited to parallel bars even with maximum support by a therapist, "assistance" if patient required minimal assistance for support or balance outside of parallel bars, "observation" if patient required observation outside the parallel bars to provide occasional assistance for balance and support. "Assistance" and "observation" patients generally could be expected to walk satisfactorily about the ward or home with an attendant or relative and thus are failures only in the sense of our definition of terms, the condition actually having improved significantly. Many in "assistance" and "observation" patients also would be expected to continue to improve following discharge and ultimately arrive in our "success" group.

## Observations on Muscular Function and Balance

Our experience would concur with Dinken[1, 2] that prolonged flaccidity is a poor prognostic sign, and also that some patients manifest an "unperception of disease," which Babinski called anosog-

Read at the Thirty-fifth Annual Session of the American Congress of Physical Medicine and Rehabilitation, Los Angeles, September 10, 1957.
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nosia, in hemiplegics manifested by lack of true awareness of the paralysis or neglect of impressions from the involved side. Gerstmann[3] felt this to be a disturbance of "body image." Apraxia is used to describe incoordination only if noted in the normal upper extremity and if motor power itself was satisfactory.

Many patients initially demonstrated atonic flail limbs, marked lack of standing and sitting balance and of righting reflexes to maintain or regain balance, and lack of awareness of the affected limbs, or anosognosia. Stages of recovery were characterized by improvement in these phenomena. Strength and awareness usually improved simultaneously, but in some instances anosognosia remained despite adequate strength, resulting in incoordinated and purposeless gross attempts at movement. This had to be differentiated from true apraxia, dyspraxia as a result of weakness or inadequate synergistic movement, cerebellar involvement, or conscious sensory or intellectual deficits. Balance and righting reflexes generally improved, but frequently not completely, and were inadequate if there was a minor breakdown in muscular function or coordination which triggered the loss of balance. Some patients never regained satisfactory balance control and required assistance or observation although all other factors were adequate for independent ambulation. We differentiated these balance problems seen in typical middle cerebral artery syndromes from those due to cerebellar syndromes, bilateral neurological involvement, or out-right muscular weakness with inability to support the body. Most of our patients went through these phases and achieved independent ambulation. The failures were usually due to one of them. No particular substitute method for advancement of the paretic limb was found to be a cause of failure in itself, but some substitute methods resulted in failure because they were unsatisfactorily executed. Many of the successes used these substitute technics.

### Initiation and Placement

Some patients showed delay in advancement of the hemiplegic leg at the beginning of the swing phase because of spasticity of the gluteus maximus, catching the foot with talipes equinus, weakness of the hip and knee flexors, spasticity of the quadriceps, or breakdown in the synergistic coordination of the normal movement with fairly good motor power, or of one of the substitute mechanisms described below.[4]

Some patients showed difficulty in the foot placing mechanism due to weakness or spasticity after satisfactory swing through:

*a.* The hemiplegic leg was advanced and held in hip flexion with the knee either flexed or extended but prevented from reaching the ground.

*b.* The leg was advanced and cross adducted.

*c.* The leg was flung forward in an incoordinated movement due to anosognosia, cerebellar ataxia, or apraxia.

### Advancement of Paretic Leg by Substitute Mechanisms

These methods are noted in both successes and failures. They were only causes of failure when they were unsatisfactorily performed and they all offer advantages under certain circumstances. It should be noted that any of these substitute methods of advancement will be impeded by factors which interfere with clearance of the leg. The paretic limb may be advanced freely or it may be dragged behind the patient.

*Circumduction.* Advancement of the leg by circumduction may serve many purposes: (1) Overcome the interference with smooth swing through of the talipes equinus by lengthening the arc; (2) achieve stable placement of the supinated foot by forceful adduction of the leg and pronation of the foot against the ground; (3) if the knee is held in extension by an active or spastic quadriceps it may minimize the supination of the foot as a result of the climbing reflex which may occur with hip and knee flexion; (4) when externally rotated the sartorius and adductors contribute to hip flexion, a wide base is provided, and the transfer of weight transversely across the joint minimizes the tendency to buckling be-

fore the weight is completely forward during the stance phase of the hemiplegic leg; (5) when spasticity or contracture of the heel cord limit dorsiflexion of the ankle during the swing phase of the uninvolved leg, there is interference with the transfer of weight forward over the hemiplegic leg causing a short normal step and a sensation of tightness in the involved calf — this restricting force is diminished when the leg and foot are in external rotation.

*Pelvic and Trunk Movement.* In order to maintain a position of extension or even recurvation of the hemiplegic knee during its stance phase for stability, the trunk may be flexed forward to advance the center of gravity and then the good leg quickly advanced in a "peg leg" fashion; this also minimizes the restraint to propulsion of the spastic heel cord.

Advancement of the hemiplegic leg can occur with lateral tilt of the trunk over the normal leg due to weight shift; lateral shift of the abdominals, gluteus medius, and quadratus lumborum to clear the hemiplegic leg; followed by posterior tilt of the trunk and anterior (upward) tilt of the pelvis by the abdominal muscles to swing the limb through. The presence of hip elevators on the involved leg aids this mechanism of advancement of the leg when hip flexors are weak.

Weakness of the gluteus medius is manifested by either a gluteus medius limp if overcompensated or more commonly by a positive Trendelenberg sign which, during walking, shortens the stance phase of the hemiplegic leg and causes a rapid "peg leg" advancement of the uninvolved leg.

The hemiplegic leg may be dragged up to the advanced normal foot or even occasionally swung through by forward flexion of the trunk over the advancing normal leg, thus "pulling" the paretic limb behind.

The paretic limb may be advanced by internal rotation of the normal hip, thus twisting the opposite half of the pelvis and paretic limb anteriorly up to or near the position of the uninvolved leg.

## Results

In the 200 cases studied, 116 (58 per cent) were in the "success" group, 52 (26 per cent) were in the "failure" group, 7 (3.5 per cent) were discharged prematurely, 16 (8 per cent) deteriorated, and 9 (4.5 per cent) were discharged as unfeasible for rehabilitation. The 52 patients in the "failure" group fell into the following categories:

True failure group. ..26 (50%) of failure group
Assistance group. ....14 (26%) of failure group
Observation group. ...12 (23%) of failure group

## Summary of Causes

Evaluation of the 52 "failures" revealed the cause of failure in ambulation to be as follows:

**True Failure Group: 26 Cases**

| No. | Cause |
|---|---|
| 18 | Muscular disability |
| 2 | Cerebellar ataxia and bilateral neurological involvement |
| 2 | Unrecovered-balance problems |
| 2 | Poor motivation |
| 1 | Anosognosia |
| 1 | Multiple complications |

**Assistance Group: 14 Cases**

| No. | Cause |
|---|---|
| 9 | Muscular disability (1 also had apraxia) |
| 2 | Poor motivation (actually could walk independently) |
| 1 | Apraxia and visual perceptual problem |
| 1 | Unrecovered-balance problem |
| 1 | Cerebellar ataxia (unilateral) |

**Observation Group: 12 Cases**

| No. | Cause |
|---|---|
| 5 | Muscular disability |
| 2 | Poor motivation (emotional problems) |
| 2 | Mental deficits (1 had visual perceptual problem) |
| 1 | Unrecovered-balance problem |
| 1 | Poor vision (cataracts) |
| 1 | General weakness and fatigability |

**Total Failures: 52 Cases**

| No. | Cause |
|---|---|
| 32 | Muscular disability (paresis, atonicity, spasticity) |
| 1 | Muscular disability, apraxia, visual perceptual problem |
| 6 | Poor motivation (2 in the "true failure" group) |
| 4 | Unrecovered-balance problems |
| 3 | Cerebellar (2 with bilateral involvement) |
| 2 | Mental defects (1 had visual perceptual problem) |
| 1 | Anosognosia |
| 1 | Poor vision (cataracts) |
| 1 | Multiple complications |
| 1 | General weakness and fatigability |

## Comments

The following factors were evaluated in each case to determine their causative role if any:

1. Mental disease other than organic deterioration, incontinence, general weakness and fatigability, and cardiac disease occurred most frequently in the "total failure" group, but in only one instance was one of these (general weakness) felt to be the cause of failure in independent ambulation.

2. Organic mental changes occurred in 20 instances of failure; poor motivation occurred in 20 instances of failure; a combination of both in 10 instances; overt depression occurred in 9 instances, which fell into all groups and occurred in 6 instances with combination of poor motivation and organic mental changes. Significant emotional lability occurred in 7 instances, and in 4 of these depression was also considered to be present. These findings occurred most frequently in the "true failure" group, but only 7 cases were due to poor motivation and 2 cases due to mental deficits.

*3. Sensory Deficits.* All patients were examined for sensory loss of pain, temperature, touch, vibration, and position sense. Where communication and intellect permitted, we found only two patients with significant loss of position sense. There were many instances of diminished sensation however. One patient with absent position sense walked independently. Our only failure with absent position sense of the toes had a "poor leg" in general, which tended to buckle at the knee, and also had a visual perceptual problem. It was felt that loss of conscious sensation was not a significant factor in preventing independent ambulation since this patient only required minimal assistance and the muscle strength picture was adequate to explain the need.

*4. Atypical Diagnostic Groups.* Among the 52 failures only five cases were diagnosed as other than involvement of the middle cerebral artery. Three of these had bilateral findings: Two instances of Millard-Gubler syndrome — one with the posterior inferior cerebellar artery syndrome and one with bilateral superior cerebellar artery syndrome — and one case of anterior cerebral artery syndrome.

The two cases of unilateral involvement were right hemiplegia superimposed on a congenital right hemiathetosis and a posterior inferior cerebellar artery syndrome causing ataxia of the ipsilateral side.

In general, cerebellar artery syndromes complicated by ataxia, tremor, and involuntary movements carried a poorer prognosis in terms of ambulation. The presence of bilateral neurological findings, often only a positive Babinski sign, also impeded recovery and occurred eight times among the failures.

*5. Aphasia.* Aphasia occurred 11 times (9 minimal, 1 global with apraxia, 1 global with other organic mental changes). In all instances the failure was explainable on a neuromuscular basis, although aphasia and apraxia interfered to some degree.

*6. Apraxia.* Apraxia occurred twice, and both cases required minimal assistance. These patients also manifested apraxia with the normal hand. One had visual perceptual problems and global aphasia; the other had multiple complications. Again it was felt that the muscle picture "poor-fair" alone was primarily responsible because of inadequate swing through, although apraxia and a visual perceptual problem contributed in one.

*7. Visual Problems.* Six instances of visual problems occurred which were felt to be significant but in only one case was it the cause for failure — the patient with hemianopsia required observation as he would hit objects and lose his balance. One case of hemianopsia and three instances of visual perceptual problems occurred in patients with atonic or poor motor power which was felt to be the basis for failure. One patient was almost blind from cataracts but failed because of multiple problems including bilateral neurological findings, emotional lability, aphasia, organic mental changes, and general weakness and fatigability despite a "fair plus" extremity.

Thus, in only one case was loss of vision considered to be the cause of

failure. Visual perceptual changes may have contributed in one patient with organic mental deficits and in one with apraxia and muscular weakness.

Various methods of determining visual perceptual deficits have been attempted. Currently we use a battery of tests consisting of the Weigl-Goldstein-Scheerer Color Form Sorting, the Goldstein-Scheerer Block Design and Stick Test and the Visual Agnosia Sub Test of the Eisenson Test. Admittedly these are tests of abstract thinking, but we attempt to differentiate from the results, instances in which the organization of visual material is distorted while abstract thinking in other areas is not as badly involved. We did not find clear-cut evidence in any case for disturbance of visual perception, such as disturbance of visual spatial or figure ground relationships, to be the primary cause of failure, although it was contributory in two cases.

*8. Muscular Function.* Failure was due to muscular weakness, atonicity or spasticity in the majority of cases.

In the "true failure" group, inability to maintain the standing position was most common and was due to weak atonic trunk and lower extremity manifested by buckling at the knee and jackknifing at the hip, or to very inadequate swing through. Many of these patients also had a loss of balance and righting reflexes and anosognosia or unawareness of the paralysis.

In the "assistance" group, 8 (includes 1 ataxic patient) of the 14 patients had difficulty with swing through and only 3 were unable to support the body weight. The former was due primarily to weakness, spasticity, or a faulty substitute mechanism throwing the patient off balance. One patient did not recover from the original loss of balance and righting reflex.

In the "observation" group, patients were able to ambulate but would occasionally lose balance due to buckling at the knee or interference with swing through or placement due to sudden spasm. It is felt that, despite a triggering mechanism, these patients retained impaired balance and poor righting reflexes. One case came into the category of unrecovered balance problem.

## Conclusion

Despite the presence of many complicating factors, by far the commonest cause of failure in ambulation in all groups in this study was muscular weakness, atonicity, or spasticity. Poor motivation was next, followed by unrecovered balance problems and cerebellar syndromes.

Instances due to anosognosia, poor vision, multiple complications, general weakness and fatigability, and mental defects occurred but were infrequent. No particular substitute technics of advancing the paretic limb were implicated as contributing to failures. It was felt that usually the best method was unconsciously chosen by the patient.

Apraxia occurred twice and was felt to be a significant contributing factor in one case in association with muscular weakness and a visual perceptual problem. Visual perceptual problems as suggested by our technics occurred in three instances, in two of which it was felt to be a significant contributing factor. Sensory loss and, in particular, position sense loss was uncommon and not found to be a causative factor in any case.

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# Bilateral Effects of Unilateral Exercise: Experimental Study Based on 120 Subjects

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● The purpose of this study was to test the bilateral effects of unilateral strength-building exercises on the elbow-flexor muscles. Sixty male college students were periodically subjected to ergometric exercises of the left elbow-flexor muscle group for four weeks. Fifteen subjects exercised twice weekly, fifteen three times weekly, fifteen four times weekly, and fifteen five times weekly. A control group of equivalent size was matched to each exercising group. The results of this study are: statistically significant increases in strength and endurance of the left (exercised) elbow-flexor muscles in the groups exercising three, four, and five times weekly; no statistically significant increases in strength and endurance of the left (exercised) elbow-flexor muscles in the group that exercised twice weekly; no statistically significant increase in strength and endurance of the right (unexercised) elbow-flexor muscles in any of the experimental groups, and no statistically significant increases in strength and endurance of the flexor muscles of either elbow in any of the control groups.

During the past decade, much attention has been given to bodily movements as important factors in the prevention and treatment of various pathologic conditions. Of particular interest has been the controversy concerning the possible bilateral effects of unilateral exercise. Although most of the evidence seems to substantiate the cross transfer of strength, the experimental designs of most of the reported studies have equivocal features. Slater-Hammel[1] summarized the most common of these as follows: (1) The sample group is too small; conclusions often have been based on results in only one or two subjects, (2) a control group is not used, (3) the unexercised extremity often is actively engaged in supporting other functions, and (4) the subject and author often are the same person.

In view of these shortcomings and of the inconclusive findings by Baer and associates[2] (the transfer of strength was of borderline significance in one and of no significance in two experimental groups), and Muller[3] (who reported no cross transfer of muscular strength), it is the purpose of this paper to briefly review the literature on this problem and then present the results of carefully controlled tests of the bilateral effects of unilateral strength-building exercises on the flexor muscles of the left elbow.

## Review of the Literature

The first investigation of the cross transfer of strength is credited to Scripture, Smith, and Brown[4] when, in 1894, they demonstrated that exercising of the right hand resulted in an increase in strength of both hands. In 1898 Anderson[5] reported similar findings. From a series of cross-education experiments, Davis[6, 7] found that systematic exercises of one part of the body greatly improved the muscular performance in other parts of the body. One of the more comprehensive studies of the cross-transfer effects of systematic exercises is that of Hellebrandt, Parrish, and Houtz.[8] They reported that unilateral exercises not only affected muscles of the exercised extremity but also affected muscles of the opposite extremity. Experimental observations by others[9-10] support these findings.

The cause of cross transfer of strength, as it was observed by those investigators, is not completely understood. Davis[6, 7] postulated that the intangible qualities of will power and attention were developed during practice, and that this development in turn improved the performance of similar acts of symmetrical and closely related anatomic parts and probably, to a lesser degree, the performance of all acts. Hellebrandt,[11] on the other hand, believes that no power of the will can induce the cortical center involved in motor learning to discharge maximally when deprived of the facilitating reflex barrage which occurs as a

Read at the Thirty-fifth Annual Session of the American Congress of Physical Medicine and Rehabilitation, Los Angeles, September 10, 1957.

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This investigation was supported in part by funds provided for biological and medical research by the State of Washington Initiative Measure No. 171.

result of maximum resistance to a movement.

After considerable study of the so-called "associated movements" of the spastic hemiplegic patient, Walshe[12] concluded that these movements were due to tonic postural reflexes arising in and acting on the limbs. Wissler and Richardson[13] postulated another theory for the cross transfer of strength when they concluded from their investigation that there is a diffusion of motor impulses from the exercised to the unexercised extremity. Combining these two theories, Hellebrandt and associates[8] stated that the cross transfer of strength results from the diffusion of motor impulses from the exercised to the unexercised side and from tonic postural reflexes arising in and acting on the extremity, which are modulated by reflex mechanisms situated in the brain stem.

Davis[14-16] gives considerable support to the theory that the transfer effects of unilateral exercise are caused by "cross-exercise." Utilizing electromyography in his investigations, he observed that certain potentials could be elicited in all four extremities upon a simple voluntary contraction of only one of them. While the magnitude of the activity of each of the other extremities was much less than that of the exercised member, Davis reasoned that it was, nevertheless, substantial enough to constitute a form of muscular exercise.

## Report of a Study

*Subjects.* This investigation was comprised of 120 male college students. Their ages ranged from 18 to 22 years, the median age being 20 years; heights ranged from 66 to 76½ inches, the median height being 70 inches; weights ranged from 127 to 218 lbs., the median weight being 169 lbs.

*Examiners.* Before an examiner was permitted to collect data for this study, he was required to demonstrate his ability in obtaining consistent test results with the other examiners on both the tensiometer and the Kelso-Hellebrandt ergometer. The degree of consistency between the various examiners was reflected in an objectivity coefficient of 0.90, or better.

*Testing Equipment.* In this study of the cross-transfer effects of exercise, both strength and endurance of the elbow flexor muscles were measured. The instrument used to record strength was a specially adapted aircraft tensiometer (fig. 1). The method employed for measuring strength was the same as that described by Clarke[17] for the cable-tension elbow-flexion test.

The Kelso-Hellebrandt ergometer[18] (fig. 2) was used to measure endurance, as well as for exercising the elbow flexor muscle group. This instrument consists of a lever arm attached to a wheel and axle which permit the angle of application of the load to remain constant throughout the motion of the arm.

Endurance was measured in terms of total distance the load was raised during a prescribed test session, and was recorded by a distance meter attached to the ergometer. The load placed on the ergometric carriage at the beginning of a test was three-eighths of maximum strength of the subject's left elbow flexor muscles as determined with the tensiometer. In a previous study[19] it was found that the three-eighths strength proportion produced the most consistent results in fatiguing the elbow flexor muscles. In computing work done, the actual load carried on the ergometer would be approximately one-half of the weight placed on the ergometric carriage, or three-sixteenths of the elbow flexor strength. The theoretical mechanical advantage of the ergometer is computed by comparing the diameter of the wheel to the length of the lever arm. In our experiments, it was 1:2.

The frequency of exercise, 30 per minute, was paced by an electric timer. The complete cycle of flexion and extension was completed in two seconds, one second for raising the load and one second for lowering the load. The subject was instructed to accomplish a smooth constant movement with no rest pauses during a test.

*Experimental Procedures.* The 120 subjects were divided into two units: a control unit of 60 and an experimental

unit of 60 subjects. The experimental unit was divided into four groups of 15 subjects each. Each subject in this unit, depending upon the group to which he was assigned, exercised his left arm on the ergometer over a period of four weeks in the following manner:

| | |
|---|---|
| Group I | Monday, Thursday |
| Group II | Monday, Wednesday, Friday |
| Group III | Monday, Tuesday, Wednesday, Thursday |
| Group IV | Monday, Tuesday, Wednesday, Thursday, Friday |

Also, every subject in the experimental unit exercised his right arm twice, once at the beginning of the 4-week program and once at the end. This of course was done in order to observe whether any transfer of strength and endurance occurred as a result of exercising the left arm.

The control unit was divided into four groups and each group was paired with an experimental group by equating the means and standard deviations of the subject's initial strength scores. These subjects exercised both their right and left arms twice, once at the beginning of the study and once at the end. Obvi-

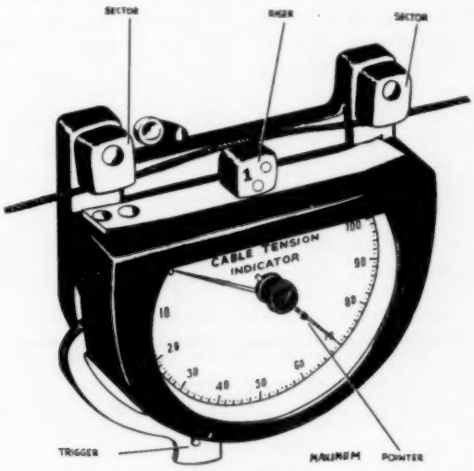


Fig. 1 — Tensiometer.

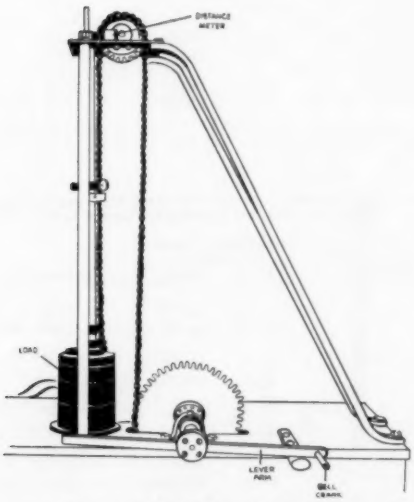


Fig. 2 — Kelso-Hellebrandt Ergometer.

ously the purpose of the control unit was to note any strength and endurance changes which occurred so that more valid conclusions might be drawn.

## Results

To determine whether each of the four groups in the experimental unit significantly gained in strength of the elbow flexor muscles, the difference between the first and last day strength gains for the exercised (left) arm was statistically tested. Table 1 contains the results of this analysis. From the table, one may conclude that the groups exercising three, four, and five times a week significantly increased their strength scores. The respective $t$'s of 2.52, 2.34, and 2.37 were statistically significant beyond the 0.05 level of confidence. The $t$ of 0.90 for the group exercising twice a week is not significant, which implies that these subjects did not experience appreciable strength gains.

Also included in table 1 are the first and last day strength means for the right (unexercised) arm of the subjects in the experimental unit. The $t$ test was applied to these means in order to determine whether or not significant strength gains were realized as a result of the cross-transfer effect of unilateral exercises. The $t$ ratios, ranging from 0.35 to 0.96 are not significant, implying of course that no transfer of strength had occurred from the exercised arm.

For comparative purposes, the difference between the first- and last-day strength means for both the right and left elbow flexor muscle groups of the subjects comprising the control unit, was tested for significance. These data appear in table 2; and the $t$'s ranging from 0.30 to 0.79 are not significant. To illustrate further the comparison between the two units, the strength gains for each of the eight groups were converted into percentages and rounded off. Figure 3 contains these data. It is interesting to observe that, for the control unit, the percentage of strength increase ranged from 1 to 3 per cent, while the range for

**Table 1: Comparison of Mean Strength in Pounds-Pull of the Exercised and Unexercised Elbow-Flexor Muscles: Experimental Unit**

| Group | Arm | No. of Exercise Sessions Per Week | Strength in Pounds-Pull, Means | | Difference | S. E. of Difference | $t$ Ratio |
|---|---|---|---|---|---|---|---|
| | | | Before | After | | | |
| I | Left | 2 | 129.00 | 134.47 | 5.47 | 6.05 | 0.90 |
| | Right | 0 | 130.40 | 132.10 | 2.10 | 6.08 | 0.35 |
| II | Left | 3 | 125.73 | 140.27 | 14.54 | 5.77 | 2.52* |
| | Right | 0 | 128.27 | 136.60 | 5.33 | 5.83 | 0.91 |
| III | Left | 4 | 136.20 | 149.00 | 12.80 | 5.47 | 2.34* |
| | Right | 0 | 142.20 | 147.27 | 5.07 | 5.28 | 0.96 |
| IV | Left | 5 | 129.33 | 140.27 | 10.94 | 4.62 | 2.37* |
| | Right | 0 | 129.67 | 132.33 | 2.66 | 4.99 | 0.53 |

*$t$ ratios of 1.76 and 2.62 denote significance at the 0.05 and 0.01 levels of confidence, respectively.

**Table 2: Comparison of Mean Strength in Pounds-Pull of the Right and Left Elbow-Flexor Muscles Before and After the Experiment: Control Unit**

| Group | Arm | No. of Exercise Sessions Per Week | Strength in Pounds-Pull, Means | | Difference | S. E. of Difference | $t$ Ratio* |
|---|---|---|---|---|---|---|---|
| | | | Before | After | | | |
| I | Left | 0 | 129.63 | 131.73 | 2.01 | 6.00 | 0.34 |
| | Right | 0 | 130.00 | 132.10 | 2.10 | 6.08 | 0.35 |
| II | Left | 0 | 126.00 | 127.76 | 1.76 | 5.83 | 0.30 |
| | Right | 0 | 128.32 | 130.33 | 2.00 | 5.62 | 0.36 |
| III | Left | 0 | 135.98 | 139.48 | 3.50 | 5.50 | 0.64 |
| | Right | 0 | 142.00 | 145.50 | 3.50 | 5.40 | 0.65 |
| IV | Left | 0 | 129.20 | 132.27 | 3.57 | 4.54 | 0.79 |
| | Right | 0 | 128.57 | 131.57 | 3.00 | 4.80 | 0.64 |

*$t$ ratios of 1.76 and 2.62 denote significance at the 0.05 and 0.01 levels of confidence, respectively.

Table 3: Comparison of Mean Endurance in Foot-Pounds of the Exercised and Unexercised Elbow-Flexor Muscles: Experimental Unit

| Group | Arm | No. of Exercise Sessions Per Week | Strength in Pounds-Pull, Means | | Difference | S. E. of Difference | *t* Ratio |
|---|---|---|---|---|---|---|---|
| | | | Before | After | | | |
| I | Left | 2 | 745.80 | 856.61 | 110.81 | 66.26 | 1.67 |
| | Right | 0 | 770.81 | 788.15 | 17.34 | 19.78 | 0.88 |
| II | Left | 3 | 831.21 | 1052.09 | 220.88 | 75.43 | 2.93* |
| | Right | 0 | 854.12 | 870.52 | 16.40 | 18.02 | 0.91 |
| III | Left | 4 | 677.48 | 867.42 | 189.94 | 69.55 | 2.73* |
| | Right | 0 | 703.84 | 720.11 | 16.27 | 19.84 | 0.82 |
| IV | Left | 5 | 723.46 | 960.99 | 237.94 | 44.62 | 5.32* |
| | Right | 0 | 755.36 | 772.01 | 16.65 | 18.57 | 0.90 |

*$t$ ratios of 1.76 and 2.62 denote significance at the 0.05 and 0.01 levels of confidence, respectively.

the experimental unit (unexercised right arm) was about the same, or to be exact, 1 to 4 per cent.

Table 3 contains the results of the analysis employed to ascertain whether the four groups in the experimental unit gained in endurance. Through testing the difference between the first- and last-day endurance means, it can be seen that for the left (exercised) arm, all but the 2-day-a-week exercise group significantly increased. The *t*'s of 2.93, 2.73, and 5.32 for the 3-, 4-, and 5-day-a-week groups respectively, are significant beyond the 0.01 level of confidence.

For the right arm the *t* ratios ranged from 0.82 to 0.91, and of course were not significant. As a result of this analysis, one may conclude a cross transfer of endurance from the left (exercised) arm to the right (unexercised) arm did not occur. Also, the same analysis was utilized for the groups comprising the control unit, and as would be expected, no significant gains were found.

## Summary

Sixty normal male college students performed ergometric exercises of the flexor muscles of the left elbow for a period of fours weeks. Fifteen subjects exercised twice per week; 15, three times per week; 15, four times per week; and 15, five times per week. On the basis of means and standard deviations of initial strength scores, a control group of equivalent size was matched to each experimental group. The bilateral effects of unilateral exercise were studied.

The findings from these experiments are as follows:

1. There were statistically significant increases in strength and endurance of the flexor muscles of the left (exercised) elbow for the experimental groups that exercised three, four, and five times per week.

2. There were no statistically significant increases in strength and endurance of the flexor muscles of the left (exercised) elbow for the experimental group that exercised twice per week.

3. There were no statistically significant increases in strength and endurance of the flexor muscles of the right (unexercised) elbow for any of the experimental groups.

4. There were no statistically significant increases in strength and endurance of the flexor muscles in either the right or left elbows in any of the control groups.

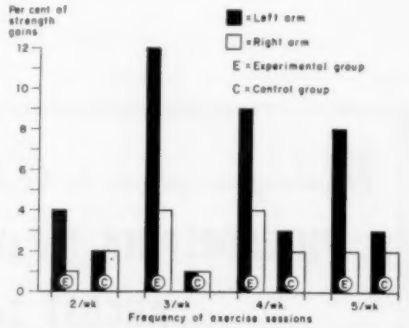


Fig. 3 — Per cent of strength gain in right and left arms of the 120 subjects.

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**PHILADELPHIA for the ANNUAL SESSION,**

**AUGUST 24-29, 1958**

# Swimming by the Handicapped

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Winter Park, Fla.

● The majority of handicapped persons can learn to swim; many can be taught to get in and out of a pool with little or no aid. Since swimming is one sport that utilizes all muscles, optimal physical conditioning can be obtained or maintained. This is a step beyond definitive underwater therapy — which it can also enhance, but which is no longer needed by a rehabilitated individual. It furnishes recreation, socialization and competition.

Swimming programs for the physically handicapped have been carried on for many years in scattered spots about the country, most often in summer camps for the handicapped and in some Y.W.C.A. and Y.M.C.A. pools. Organized programs, however, with the teaching of recognized strokes as a part of a total rehabilitation program are comparatively new. With the publication in 1955 of an instructor's manual, *Swimming for the Handicapped,* by the American National Red Cross,[1] we can anticipate and hope that more handicapped persons will have an opportunity to participate in this activity. It would follow that more physicians will be called upon to assist and advise these Red Cross instructors.

Purposeful swimming has physiological and psychological advantages beyond "underwater exercises,"[2] which are so valuable, as advocated and first carried out by Dr. Charles L. Lowman of Los Angeles as early as 1911. Underwater exercises for muscle re-education are an important form of definitive treatment, but there comes a time in any physical disability when gross motion, rather than individual muscle action, is advantageous. Possibly no other physical activity but swimming calls upon the simultaneous use of every muscle in the body. An attempt to do scientific swimming strokes also tends to increase range of motion, calls for control of body movements with rhythmical motions, and promotes deeper breathing.

When a handicapped person has been taught to get in and out of a pool or lake without any physical assistance, and to actually swim about in freedom and security without the impedimenta of braces, crutches, or wheelchairs, and use extremities that move easily in the water which they do not do on land, then this independence is a goal the attainment of which is obvious and most pleasureable. A challenge is presented to obtain this freedom. With it goes fun and socialization. In the water, too, the physical deformities are not so obvious to others. Many physically handicapped persons can learn enough swimming skills so that, for the first time, they are able to participate in an activity along with normal persons. The purpose of this paper is to re-emphasize these facts.

A physical examination and a physician's written permission for a handicapped person to participate in a swimming program is a wise precaution. The permission can become a prescription in which the most advantageous motions can be indicated, and precautions listed, which the instructor must learn to keep in mind. Routine examinations always include the condition of the heart, lungs, ears, and sinuses. An instructor also needs to know if the person is partially sighted or blind, hard of hearing or deaf, and if he has a tendency to have convulsions. The instructors should be taught and be ready to deal with a convulsion, if one occurs. While accidents to handicapped persons in a well-controlled safety program are not anticipated, problems of vision, hearing, and convulsions are the three most likely to be the cause of them.

## Red Cross Instructor's Manual

The American National Red Cross instructor's manual on handicapped swimming is well done. A physical examination is recommended which covers all necessary points except the three I have mentioned, but problems of sight and hearing are discussed elsewhere in the manual. There is a discussion of the concept of total rehabilitation, of under-

Read at the Thirty-fifth Annual Session of the American Congress of Physical Medicine and Rehabilitation, Los Angeles, September 12, 1957.

Medical Director and Administrator, Kirkpatrick Memorial Institute of Physical Medicine and Rehabilitation.

standing the handicapped person, the value and objectives of an organized swimming program, and methods of teaching. There is a breakdown and analysis of joint motions that can be expected with specific types of physical disabilities, and a pictorial chart of joint motion.

The Red Cross is constantly expanding their water safety programs, and training as many instructors as possible. The training courses follow in qualifying sequence. This course can be greatly enhanced if physicians express their interest and volunteer to give some lectures, or even be the instigators for the development of such a program in their own communities.

### Community Programs

The instructors will not be lacking, nor will volunteers. Many handicapped persons need to have someone stay beside them as they are learning, while a few — such as those with stiff hips — always need someone to get them into the water in a horizontal position, or bring them to an upright position when they are ready to get out. We have found this kind of assistance easy to obtain. The District Director of Water Safety in Orlando, Florida used Junior Life Savers as assistants with the children from the Crippled Children's School in their summer program in 1956 and 1957. All of the 25 children enrolled in the summer school participated in 1957. There were sufficient volunteers, with half the group swimming every morning, the others every afternoon week days, for six weeks. I can obtain more volunteer assistants and assistant instructors for the adult program than I can find handicapped adults who want to make the effort to learn to swim.

The National Director of Water Safety of the American National Red Cross is interested in expanding handicapped swimming programs across the country. In 1957 he was invited to meet with representatives of the United Cerebral Palsy Associations, Inc., to help them work out a more specific recreation program for their affiliates; swimming was one important aspect of their planning program. One such workshop is scheduled to be held at Vero Beach, Florida in the summer of 1958. This program is not limited to instructors working only with cerebral palsy patients.

### Learning Independence

One of the things *not* mentioned in the instructors manual is the carry over of activities of daily living; first in dressing and undressing; then in learning to get in and out of water without assistance. I have often seen children, or even adults, carried to the pool, and lifted into the water in other programs. A civic club in one community program donated and installed an electric hoist over the pool, and with the appropriate ceremony. This emphatically is the wrong approach. Electric hoists are an absolute necessity for Hubbard Tanks and some therapeutic pools when the patient is helpless, but swimming *by* the handicapped includes learning to enter and leave pools and lakes, just as normal people do.

From the very start the handicapped should learn how to get from wheelchair to the ground, and back into the chair. If they cannot walk, they should be expected to crawl or scoot to the water. Their training should be in both pool and lake whenever possible, because of the different methods required to enter and leave the water. If it happens to be a pool instead of a lake, they should be taught to sit on the side of the pool and fall or ease themselves in, rather than have someone lift them in. An assistant should stand in the water to offer help on the entree only when it is really needed. It is remarkable how soon they learn to dive in from a sitting position from the side of the pool as soon as they have gained confidence and learned the rudiments of swimming.

Getting out of the pool poses more difficult problems, which are a challenge but an important step in independence. Paraplegics can be trained to pull themselves up the ladder of a pool, and I have trained some to pull themselves up the side of a pool, or steep lake bank without a ladder. Even if the pool has steps which they can scoot up, they should

learn all possible methods, so that they can be independent in any other situation.

### Body Balance

The instructors need some medical guidance so that they have a general idea about the difference between spastic and flaccid paralysis, and the difference in body balance in relation to the most common disabilities of the paraplegics, amputees, hemiplegics, cerebral palsied, or orthopedic disabilities presenting various joint limitations. Body balance is possible for all handicapped persons, but tends to vary with each disability type. For example, the legs of a complete or partial paraplegic will rarely float in line with the trunk, but will drag along in various positions under his body. An instructor must learn that he is not to spend an entire season in trying to teach a proper body position for face and back floating, but to accept any position possible in which the patient can float; then go on to teach arm strokes only — of which, for the paraplegic, breast and back strokes are the best. When these are accomplished, a paraplegic can also develop a very excellent arm crawl, and with proper breathing. Since paraplegics cannot bear weight, their next goal is to develop endurance, and as a safety factor, increase the distances they can swim. Fifty to one hundred yards is a beginning goal; working toward a quarter to even a half-mile swim (under supervision) is something to really work toward — and for which a visible award should be provided.

### Breathing and Floating

Rhythmical breathing and "bobbing" is taught to everyone. They support themselves on their hands alone, or in a kneeling or crawling position in shallow water. Many are physically capable of also doing some of the beginning stunts devised for other beginners that are simple and fun enough to have them learn to get their heads under water without fear. All must learn back and face floats and, particularly, how to turn on to their backs to rest — even if their disability is such that a side stroke is the only stroke they can possibly learn to use. As soon as any swimmer can get into deep water, he can be taught to tread water, using his legs alone, or his arms alone, or even one arm and one leg.

### Swimming Strokes

The types and variety of swimming strokes that can be taught and successfully used, of course, depend upon the type of disability and amount of involvement. A hemiplegic might well be only able to go in a circle if he actually is able to use only the arm and leg on one side. To him, the side stroke is basic, but he should have instruction and try the back and breast stroke. He may have more use of the involved side in the water than he or anyone else (even including a physiatrist), anticipated. Also, by practice, and because the goal is visible as well as a challenge, he may develop motor powers that have been dormant, only because he did not try hard enough in his definitive treatment program. Nor can one always tell which strokes an amputee (whether an upper or lower extremity loss) or an arthritic can do, without trying.

### Artificial Swimming Aids

Artificial gadgets are rarely useful and most often dangerous. To depend upon a rubber ring which may puncture or the valve leak, rather than actually learn to float, is one example. What is more, these gadgets are not designed to overcome disturbed body balance, so they can rarely be attached in an advantageous position. They only delay the development of confidence or the overcoming of fear and the actual learning of any swimming skill. When they have been used, taking them away is just like weaning a person from a walker, then having to teach proper body balance and re-train proper walking patterns all over again.

All Red Cross water safety programs emphasize that inflated rubber tubes, water wings, and other floating supports should never be used, even for non-handicapped persons, for two reasons. First is the delay in learning to float and

swim that we have mentioned. Secondly, nonswimmers who venture into deep water on their rubber floats or playthings may drown, if they deflate for any reason.

Nevertheless, in preparing the handicapped manual, the idea was outlined that various floating devices could be attached to a handicapped person's belt or legs so that his body would then be suspended in the same position that the bodies of nonhandicapped persons assume in floating or swimming properly. But no matter what position the flail legs of a paraplegic might take in the water — sometimes the legs under the body with almost full flexion at the hips — nature makes the adjustment. When one tries to support these legs in proper body alignment, the paraplegic's head goes under. The only thing to do, if that individual is going to learn to float or swim, is to let his legs trail where they will. When our local water safety director first started teaching the children in 1956, he prepared the recommended gadgets. Within a week, he had had to abandon all of them. No matter where they were strapped on, they threw every child out of any alignment so that they could not attain any position in which their bodies would float.

The one gadget that I have found of some use are the rubber fins. They will make swimming easier for some hemiplegics, particularly if the individual has fair motion in the affected leg. They may also assist an individual who has limited motion in the hips or knees. Some of these persons find that with fins they can propel themselves further through the water with greater ease and with more endurance.

### Swimming Awards

A purposeful program sets goals and provides awards. The official Red Cross beginners, intermediate and advanced swimmers courses do this. Most handicapped persons can learn to pass the beginners course; some, the intermediate; a few, the advanced tests. When certain strokes are impossible in advanced swimming, increased distance swimming, or endurance in keeping afloat may be substituted. Cards and identifying buttons are given in each grade. The awards are the same for the handicapped as for the nonhandicapped, so definite evidence is presented to show that they have been capable of meeting the same standards set for normal persons.

None of the 25 children in the school program were able to pass the beginners course in 1957, but their instructor is sure that the majority of them will do so in 1958. One would anticipate that they would learn slowly because of their severe handicaps and because they only had six weeks actual swimming experience in 1957. Also, when the instructors themselves become more familiar with handling the handicapped, they will probably learn methods to facilitate the teaching. The gains that have been made in these children's physical improvement have been considered tremendous in only this short time.

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# medical news

*Members are invited to send to this office items of news of general interest, for example, those relating to society activities, new hospitals, education, etc. Programs should be received at least six weeks before date of meeting.*

### George Morris Piersol Honored

*Dr. Piersol*

At a chapter gathering of the Eastern Pennsylvania Chapter of the Arthritis and Rheumatism Foundation, Doctor George Morris Piersol was awarded a certificate of merit. The award was based upon outstanding services rendered the chapter in its administration and program in eastern Pennsylvania.

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### Testimonial Dinner Held for Dr. de Victoria

On Thursday, April 17, at the Lambs Club in New York City, the Latin-American Congress of Physical Medicine, the Pan-American Academy of General Practice and the Spanish-American Society of New York honored Doctor Cassius Lopez de Victoria at a testimonial dinner. The occasion was recognition of Dr. de Victoria's thirty-one years of service as a member of the staff and faculty of Columbia University Medical Center. Among those serving on the arrangements committee for this program were Doctors Norman E. Titus, William Bierman, Hans J. Behrend, Jerome Weiss and Madge C. L. McGuinness.

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### Excuse Please . . .

Due to an unintentional error, the name of Dr. Alvin B. C. Knudson, Washington, D. C., was omitted from the membership roster of the American Academy of Physical Medicine and Rehabilitation published in the April, 1958 issue of the ARCHIVES.

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### Exclusive Translation Rights to 20 Russian Scientific Journals

The exclusive world-wide right to translate and publish complete English language editions of 20 Soviet scientific and technical journals has been granted to Consultants Bureau, Inc., under the terms of an agreement reached between Mezhdunarodnaya Kniga, Soviet publications export agency, and the New York publishing firm. Journals covered by the agreement include leading Soviet publications in physics, chemistry, electronics, metallurgy and biology and medicine.

Most of the journals covered are already being translated by the bureau, on a yearly subscription basis. The new agreement will make it possible for the publisher to shorten the time interval between date of publication of the original journal and of the translated edition, through expedited receipt of the material for translation. Copies of photographs appearing in the journals are also to be provided, so that quality of reproduction will be improved.

In addition to cooperation in the express-translation-publication project, the Soviet agency has agreed to inform Consultants Bureau in advance about changes in size or frequency of journals, projected supplements and special issues. Consultants Bureau will receive advance information about new Soviet publications. Information as to the publishing plans of various Soviet scientific and

technical bodies will also be provided to the New York agency, and this information will be promptly passed on to the Western scientific world.

Consultants Bureau has commited itself to publication of the following journals in translation for 1958: Biochemistry; Bulletin of Experimental Biology and Medicine; Proceedings of the Academy of Sciences, U.S.S.R.; Journal of General Chemistry; Journal of Analytical Chemistry; Journal of Applied Chemistry; Chemistry Section of the Bulletin of the Academy of Sciences, U.S.S.R.; Automation and Remote Control; Colloid Journal; Metallurgist; Microbiology; Plant Physiology; Journal of Technical Physics; Journal of Acoustics; Pharmacology and Toxicology; Crystallography; Theory of Probability and Its Applications; Astronomical Journal; Optics and Spectroscopy; Experimental Instruments and Techniques.

All translations are to be so scheduled that by the end of 1958, none of the translated editions will be more than six months behind the publication of the original Russian journals. In most cases, the translation will be even more prompt than this, Consultants Bureau predicts.

Complete information regarding the Consultants Bureau translation program is available without charge from Consultants Bureau, 227 W. 17th St., New York 11, N. Y.

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### Results of Research and Development in the U.S.S.R.

Pergamon Institute, a non-profit foundation, has recently been formed in Washington, D. C., and is in course of formation in London, for the purpose of making available to English-speaking scientists, doctors and engineers (from all countries that are members of the United Nations), the results of scientific, technological and medical research and development in the Soviet Union and other countries in the Soviet orbit. The International Council of Scientific Unions, during the recent meeting of its Executive Board in Brussels, decided to include a token subvention to the Pergamon Institute in the allocations for 1958, in recognition of the value to international scientific activity of the Aims and Purpose of the Pergamon Institute. Over one hundred scientists of international standing from many countries have given their support and will supervise the affairs of the Institute.

The formation and purpose of the Institute was much influenced, among other things, by a report to the United Kingdom Government by its Advisory Council on Scientific Policy, under the Chairmanship of Sir Alexander Todd, F.R.S., which, among other things, analyzed the position as follows: ". . . There would, of course, be no problem if Russian were widely read, but our information is that only about two per cent of our working scientists can read Russian, compared with 80 to 90 per cent who read French and 60 per cent German. The first thing to be done, therefore, is to encourage the teaching of Russian as an important modern language in schools and universities . . .". Authoritative sources in the United States also agree that less than two per cent of the working scientists in America can read Russian.

Allan T. Waterman, Director of the National Science Foundation in his recent report to President Eisenhower "Basic Research — A National Resource" said that "recently several American industrial laboratories spent five years and at least $200,000 conducting studies of the design of electrical circuits only to find afterwards that the work had already been done. It was described in a Russian article published in a Soviet journal before the studies started." He went on to say . . . "From published Russian sources, it appears that some 24,000 scientists, or about 14 per cent of Soviet scientific manpower, devote their time to basic research. This figure is probably somewhat higher, say between one-fifth and one-third, than the number of scientists — on a full-time equivalent basis — engaged in basic research in the United States. The Soviet Union spent more than 11.6 billion roubles on research and development in 1955, somewhat in excess of 1 per cent of its gross national product, and the proportion that went to basic research is unknown. However, the proportion is presumably less than that based on manpower estimates. These and other facts suggest the following picture:

1. A remarkably high rate of industrial and technological growth, as indicated by the high rate of increase in gross national product.
2. An even greater relative increase in research and development as indicated by the increasing ratio of research and development to gross national product.
3. A country still technologically underdeveloped, as indicated by the low starting level of its research and development — and the low level which still prevails — relative to the United States.
4. A relatively heavy emphasis on basic research certainly heavy if compared with the United States, but differing from our situation in the authoritarian controls exercised in a dictatorship."

As a result of recently announced scientific and technological developments in the U.S.S.R. there is a great need, as well as pressure, from scientists, universities, government departments and industrial firms, to overcome the language barrier and to make available rapidly in English the significant

results of research and development in the U.S.S.R. in the fields of science, technology and medicine.

It is one of the primary tasks of the Pergamon Institute to fill this need quickly by the initiation of large-scale translation programs of complete journals and books, as well as individual papers, in all the critical fields of science, technology and medicine.

The following are the projects which have already been started or are being planned by the Institute in association with and with the financial assistance of various Government departments, learned societies and private organizations, and some of the services which are available:

1. It is planned to hold a symposium during the summer of 1958 either in Washington or London, sponsored by the Institute and several interested Universities, to examine the following problems:
   a. how to assist with the establishment of extra-curricular courses for the teaching of Russian in the science, medical and engineering faculties at higher seats of learning in the English-speaking world.
   b. how to teach the reading of Russian scientific and technical texts to scientists and technologists in the minimum amount of time.
   c. what tools of learning are required.
2. Discussions are taking place with the relevant authorities in the U.S.S.R. on the commissioning of a series of review volumes, with complete bibliographies, covering broad areas of Russian scientific, medical and technical progress for the period 1920-1956.

*Journals being translated by the Institute and now available in an English edition*

The Institute now publishes a number of selected Russian journals in translation: Atomnaya Energiya (Atomic Energy); Problems of Virology; Problems of Hematology and Blood Transfusion; Journal of Microbiology, Epidemiology and Immunobiology; Biophysics; Problems of Oncology; The Sechenov Physiological Journal of the U.S.S.R.; Elektrichestvo (Electricity); Physics of Metals and Metallography; Abstracts of U.S.S.R. Metallurgy; Bulletin of the Academy of Sciences — Geophysical Series; Abstracts of Geophysics — U.S.S.R. Eastern Europe and China; Radio Engineering; Radio Engineering and Electronics; Telecommunications, and Applied Mathematics and Mechanics.

*Translation program of important Russian books*

The Institute is also assisting with the translation and publication of important Russian books on science, technology and medicine and the following titles will soon be available in English, including the work of Academician N. Semenov, who recently shared the Nobel Award for Chemistry with Sir Cyril Hinshelwood, and the classic course of Theoretical Physics by Academician Landau and his colleague, Professor Lifshitz. Academicians Semenov and Landau and Professor Lifshitz are cooperating with the Institute in bringing their books up-to-date, by adding a great deal of new and hitherto unpublished research results. Among the books being translated are: Theoretical Astrophysics; Quantum Mechanics; Statistical Physics; Mechanics of Continuous Media; The Solar Corona; Relay Protection of Power Systems; Theory of Space, Time and Gravitation; Ferromagnetism; Some Problems of Chemical Kinetics and Reactivity; Nitration of Hydrocarbons and other Organic Compounds; Boron-Fluoride and its Compounds as Catalysts in Organic Chemistry; Topological Methods in the Theory of Non-Linear Integral Equations; Integral Equations and their Applications to Certain Problems in Mechanics; Mathematical Physics and Technology; Aerodynamic Survey of Helicopters; Automatics of Aeroengines; Gas Turbine and Ram-Jet Aeroengine Regulation; Gas Turbine Aeroengines; Changes in Micro-organisms; Studies on Rickettsia and Rickettsioses; Hemorrhagic nephro-nephritis; Problems of the Pathogenesis and Immunology of Tumours, and Theoretical and Practical Problems of Medicine and Biology in Experiments on Monkeys.

*Institute services*

The services of the Institute are available to learned societies, government departments, trade associations, individual scientists, doctors and engineers. Any person in these categories wishing to keep informed of what is being published in the U.S.S.R. and other countries in the Soviet orbit may apply to the Institute to receive, free of charge, a monthly contents list in English of all the significant articles and books being currently published in his field of interest in these countries. Persons interested in any article mentioned in these contents lists may order from the Institute a full English translation which will be supplied with a minimum of delay. The charge for such a translation will be on a cooperative cost-sharing basis. This means that the costs will be shared equally with others requesting the article. The costs will be assessed on orders obtained for this translation over a period of six months and the charges to recipients of these papers will be made six months after the first request.

The Institute will undertake to supply, on request, detailed and exhaustive bibliographical information on work published in the U.S.S.R. and other Soviet orbit countries on all subjects in the field of science, technology and medicine; such services will be quoted for and charged at cost.

The Institute with the assistance of its

scientific staff will undertake, on request, critical evaluation and selection of any work published in the field of science, technology and medicine in the U.S.S.R. and other Soviet orbit countries. The Institute will also provide abstracts and résumés of such publications.

The Institute will provide, with the cooperation of the respective National Academies of Sciences of the U.S.S.R. and other Soviet orbit countries, to learned societies, government departments and industrial organizations, books and journals published in the U.S.S.R. and the Soviet orbit countries, including micro-cards and micro-films when available of books and articles published over the past twenty years in these countries, including material published during the 1939-1945 war as far as available.

The Institute will undertake the additional translation of selected journals and books if suitably recommended by learned societies, government departments or trade associations.

The Institute can undertake, with the aid of its expert panel of translators, resident all over the world, translation work in all branches of science, technology and medicine from and into any language, including Chinese and Japanese.

The Institute will make available to learned societies and individual scientists, doctors and engineers throughout the world reciprocal services on the same non-profit basis in return for their cooperation.

*Qualified translators urgently needed*

The Institute is urgently in need of qualified scientists, technologists and doctors with a knowledge of the Russian language who would be able and willing to undertake translation work on a spare-time basis for which they would be remunerated.

*Financial support and other assistance needed*

Non-profit foundations, industrial corporations, government departments, learned societies and individual scientists desiring to assist in any way with this important program should write to the Administrative Secretary of the Institute, 122 E. 55th St., New York 22, N. Y., outlining their ideas and suggestions.

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### Schering Corporation to Sponsor 200 Audio Digest Subscriptions

Schering Corporation, pharmaceutical manufacturer, has announced that as part of its continuing Audio-Educational Grant Program for resident physicians and interns, it is sponsoring 200 one-year subscriptions to "Audio Digest," a service consisting of tape recordings of important medical articles, clinical reviews and lectures, for teaching hospitals in the United States. Produced by the Audio Digest Foundation, a non-profit subsidiary of the California Medical Association, each tape contains two half-hour sessions and can be played by individuals or to groups at the convenience of the listener. In addition, each tape will include a report of important research developments at Schering.

In announcing the subscriptions, Dr. John N. McDonnell, vice president of Schering Corporation, said, "Today's constant research and developments come about faster than they can be printed. The field of medicine has become so complex that there are now over 6,000 medical and scientific journals. The intern no longer has the time to read but a few of these important publications which reach the hospital library.

"In an effort to help solve this serious problem, Schering is making this valuable service available to 200 teaching hospitals. We look on this service as an ideal means of helping the busy interns continue their postgraduate medical education."

The "Audio Digest" subscriptions will consist of a total of 122 tapes to be sent out biweekly. The Schering subscriptions will include 26 tapes on general practice and 24 each on the subjects of surgery, internal medicine, obstetrics and gynecology, and pediatrics.

The new educational service features lectures by prominent medical men, each one usually delivered in the author's own voice. The lecturers serve without pay to the Audio Digest Foundation, as do the Board of Editors and a panel of some 100 consultants. All revenue over the cost of production and distribution is contributed to the nation's 79 medical schools through the American Medical Education Foundation.

The first 90 subscriptions began in April.

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### Up-to-Date Russian-English Acoustics and Ultrasonics Glossary

A modern *Russian-English Acoustics and Ultrasonics Glossary,* containing 10,000 Russian terms, covering acoustics, ultrasonics, and electro-acoustics (with particular emphasis on the rapidly growing field of ultrasonics), has just been published by a New York firm. The Glossary, priced at $10.00, includes many terms culled by the publisher's own staff of physicist-translators from translations of thousands of pages of the most recent issues of Soviet physics and engineering journals, especially the Journal of Acoustics, the Journal of Technical Physics, and Radio-Engineering, as well as from Russian acoustics texts. The 193 pages comprising the Glossary include a 23 page index of Russian-English equivalents for names of authors commonly found in acoustics and ultrasonics literature; the Glossary proper also includes Russian equivalents for terms selected from the following: IRE Standards;

the International Dictionary of Physics and Electronics; the Russian translation of L. Bergman's "Ultrasonics Theory." This Russian-English glossary, the fourth and latest in a series which Consultants Bureau is publishing in eight specialized fields of physics, may be ordered from Consultants Bureau, Inc., 227 W. 17th St., New York 11, N. Y.

Free catalogs describing Consultants Bureau's own Russian translation-publishing program, and detailing the pre-publication Dictionary subscription offer, are available on request.

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### Medical College Studies Rehabilitation

The New York Medical College has begun a study to determine what rehabilitation can provide for the aged and chronically ill, a director of the school announced. Dr. Jerome S. Tobis, professor and director of the college's department of physical medicine and rehabilitation, said 300 welfare patients now in private nursing homes will be selected for the study.

Dr. Tobis told the National Geriatrics Society that the two-year experiment will work in the following way: one hundred of the group selected will be left in nursing homes with no change in procedure. Another 100 will be transferred to rehabilitation centers, where the most modern therapy methods will be tested. A third group of 100 will receive this test therapy in nursing homes. Of the 28 million people suffering from chronic illness in this country, 40 per cent are 65 or older, Dr. Tobis said. By 1975 every able-bodied worker in this country will be supporting a disabled one, either young or old, he predicted.

Part of the problem of rehabilitation, especially for the aged, is a social one, he said, because there has been a change from the three-generation family to a streamlined society where the elderly often cannot live with their children.

Another doctor told the Geriatrics Society that any rehabilitation which considers only the physical and material needs of the patient will fail eventually. Dr. Bernard Stoll, Chief of the Physical Medicine and Rehabilitation Services at the VA Hospital in New York, emphasized the importance of "kindness, sensitivity and ardent care."

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### International Congress of Balneology

The Czechoslovak Society of Physiotherapy is holding an International Congress of Balneology in Marienbad, September 8-13, 1958. Papers will be read by well-known scientists from Bulgaria, France, the German Democratic Republic, the German Federal Republic, Hungary, Poland, the Soviet Union, Sweden and Czechoslovakia.

The official languages of the Congress are English, French, Russian, German, Czech and Slovak. All papers will be read in these languages. There will be simultaneous interpretation to and from the official languages. Application and inquiries should be addressed to the Secretary, International Congress of Balneology, Reznicka 5, Prague 2, Czechoslovakia.

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### Recent Publications by Members

Robert M. Stecher, "The American Rheumatism Association—Its Origins, Development and Maturity." Arthritis and Rheumatism, February, 1958.

Edward W. Lowman, "Rehabilitation of the Rheumatoid Cripple: A Five Year Study." Arthritis and Rheumatism, February, 1958.

Anthony C. Cipollaro, "Contact Dermatitis Due to Thermo-Fax Paper." A.M.A. Archives of Dermatology, March, 1958.

Raoul C. Psaki and co-author, "Parkinsonism in an Oriental Treated by Chemopallidectomy." U. S. Armed Forces Medical Journal, March, 1958.

Edward T. Edwards, "The Physician and Rehabilitation of His Hemiplegic Patients." The Journal of the Indiana State Medical Association, March, 1958.

O. Leonard Huddleston and co-authors, "The Spring Wrist Cock-up Splint." The American Journal of Occupational Therapy, March-April, 1958.

Lewis A. Leavitt and co-author, "Working Philosophy of Industrial Therapy." American Archives of Rehabilitation Therapy, March, 1958.

The following articles were published in The Journal of the American Medical Association:

S. M. Reichel, "Shearing Force as a Factor in Decubitis Ulcers in Paraplegics." (February 15, 1958).

Edward M. Krusen and co-author, "Compensation Factor in Low Back Injuries." (March 8, 1958).

F. B. House and co-author, "Specific Management for Lumbar and Sacral Radiculitis." (March 15, 1958).

Arthur L. Watkins and co-author, "Rehabilitation of Persons with Bilateral Amputation of Lower Extremities." (March 29, 1958).

O. Leonard Huddleston and co-authors, "The Spring Opponens Splint." The American Journal of Occupational Therapy, January-February, 1958.

Harold N. Neu, and co-author, "Psychosocial Factors in Home Care Programs of

Long-Term Respirator Patients." Journal of Chronic Diseases, February, 1958.

Max V. Weinstein and co-author, "The Use of Magnesium Sulphate Iontophoresis in the Treatment of Subdeltoid Bursitis." The Physical Therapy Review, February, 1958.

G. Keith Stillwell and co-author, "Physical Treatment of Postmastectomy Lymphedema." Proceedings of the Staff Meeting of The Mayo Clinic, January 8, 1958.

Herbert Kent, "What Physicians Should Know About Respirators." The Southern Medical Journal, December, 1957.

Frederic J. Kottke, William G. Kubicek, and co-authors, "Studies of Cardiac Output During the Early Phase of Rehabilitation." The New Physician, May, 1958.

Howard A. Rusk and co-author, "Retirement Problems." Journal of Chronic Diseases, May, 1958.

Rex O. McMorris and co-author, "Rehabilitation in Sequelae of Acute Carbon Monoxide Poisoning." The Journal of the Kentucky Medical Association, May, 1958.

Donald A. Covalt, "Early Management of a Patient with a Stroke." Medical Times, April, 1958.

Morton Hoberman and co-author, "Teaching: A Factor in Functional Training." The Physical Therapy Review, April, 1958.

Herbert W. Park, "Clinical Results with Methocarbamol, A New Interneuronal Blocking Agent." The Journal of the American Medical Association, May 10, 1958.

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## Newly Registered Therapists

### January 1, 1958

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Andrau, Yvonne J., Woodstock, N. Y.

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# abstracts

**The Value of Irradiation in Ankylosing Spondylitis. N. Howard.** Brit. J. Radiol. **30**:371 (July) 1957.

The author reviews 455 patients treated with radiation therapy who were followed for more than two years after treatment, roughly divided into three equal groups of two to five years (31%), five to ten years (38%), and over ten years (31%). Several points of significance are brought out. Of 100 patients chosen at random, 18 per cent had low white blood counts (below 4000/cu. mm.) during or immediately following treatment by the method of University College Hospital, London.

Twenty women, aged 20 to 40 years, received radiation to the sacroiliac or hip joints. Of these, only five continued to menstruate without alteration after treatment. There were only seven pregnancies in the total series, of which two went to term, three were terminated because of pain, and two miscarried. There were 20 cases of pulmonary tuberculosis.

Improvement, judged with regard to ability to work and lead "normal social lives" even with occasional bouts of backache, occurred in 77 per cent of the patients. Of 81 patients where follow-up x-rays were made, because of suspected progression in most patients, only 15 showed advance of the disease.

Leukemia, as reported in other series, occurred in two cases. Three other deaths from malignant neoplasms and three known living patients with neoplasms are reported.

The author believes the treatment is still justified in typical cases of ankylosing spondylitis in spite of the two cases of leukemia in this series and suggests precautions regarding gonadal protection to prevent what appears to be a statistically greater threat.

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**Is There a Pyramidal Tract? Paul C. Bucy.** Brain **80**:376 (Sept.) 1957.

It is the author's contention that terms "pyramidal tract" and "pyramidal syndrome" are erroneous and misleading. He cites evidence accumulating in the literature for almost 25 years that the syndrome of hyperactive deep tendon reflexes, absent abdominal reflexes, and the sign of Babinski does not result from interruption of the corticospinal fibers which arise in the precentral gyrus and pass downward through the cerebral peduncle. Four histories together with related cases from the literature in which various portions of the cerebral peduncles have been sectioned are presented. These cases demonstrate that section of the medial and lateral segments of the cerebral peduncle has little or no effect upon either normal or abnormal muscular movement. Section of the central half of the cerebral peduncle which contains the corticospinal fibers arising from the precentral gyrus has a marked effect in abolishing or reducing abnormal involuntary movements. However, such a section does not produce spastic paralysis with hyperreflexia. On the contrary, there is in some patients "nearly normal muscular activity and many are capable of delicately controlled, well coordinated, strong movements, even of the individual digits of the affected extremities." In view of these findings the author urges renewed effort to discover and define "the neural mechanism responsible for the control of skeletal muscular activity."

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**A Comparison of Monoureide and Diureide Sedatives with Respect to Drug Habituation, Untoward Effects and Mortality Rates. T. M. Feinblatt; H. M. Feinblatt, and E. A. Ferguson, Jr.** J. Nerv. & Ment. Dis. **125**:335 (Apr.-June) 1957.

A comprehensive review of medical literature and 371 patient studies showed that two monoureide derivatives of carbromal, namely acetylcarbromal and bromisovalum, are not habit forming whether used singly or in combination. Sedayson (a combination of acetylcarbromal 150 mg. and bromisovalum 100 mg.) and also acetylcarbromal 300 mg. and bromisovalum 200 mg. tablets, when used in full dosage over long periods of time, were negative as to the criteria of drug habituation; namely, pleasurable sensations, tolerance, psychological craving and withdrawal symptoms. Daily dosages of 6-8 Sedayson tablets, acetylcarbromal 1.8—2.4 gm. or bromisovalum 1.2—1.6 gm. were given. All patients were observed closely during treatment and for an adequate period of weeks after medication was discontinued. Because of a chemical relationship, the monoureides (carbromal, acetylcarbromal and bromisovalum) have been classified mistakenly as habit forming. However, one cannot predict the physiological action of a drug with any degree of certainty from its chemical structure. Due to the fact that the monoureide sedatives are not habit forming, have no side effects, no hangover and no contraindications, their use in combination

is much preferable for continued use as a sedative or somnifacient to the dangerous and habit forming barbiturates.

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**The Cervical Spine. Anatomical-Pathological Study of Seventy Specimens with Particular Reference to the Problem of Cervical Spondylosis. Eric D. Payne, and John D. Spillane.** Brain **80**:571 (Dec.) 1957.

The authors x-rayed, dissected, sectioned, and stained 70 cervical spines from routine autopsies to clarify the normal and abnormal anatomy and pathology of this region. They were particularly interested in the problem of cervical spondylosis. The spines were from patients ranging in age from zero to 89 years, 63 of whom were over 40 years of age. They studied all aspects of the cord, cervical nerves, discs, vertebral bodies, joints, and blood supply. Of particular interest was the presence of degenerative changes in 115 of the 326 discs examined and the frequency of its occurrence at the various levels in the neck, i.e., C5-C6 disc was most commonly narrowed whereas the C7-T1 disc was most infrequently involved. They also demonstrated quite convincingly the fallacy in the older concept of "Luschka joints" with histological evidence to prove their findings.

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**Vertigo and Dizziness. D. M. Palmer.** Ohio M. J. **54**:183 (Feb.) 1958.

Positioning of the body in space is accomplished by sensory information brought in from receptors of the vestibular mechanism, eyes, tactile receptors (soles of the feet), and muscle-tendon receptors (lower limbs, back, and neck). In this article the author discusses the anatomy and physiology of these various systems and how disruption of them causes vertigo and dizziness. Symptoms of the various diseases causing vertigo were also discussed along with the generally accepted treatments.

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**Hyperextension Injuries of the Cervical Spine. Eben Alexander, Jr.; Courtland H. Davis, and Charles H. Field.** A.M.A. Arch. Neurol. & Psychiat. **79**:146 (Feb.) 1958.

The problem of hyperextension injuries to the cervical spine resulting in neurological deficits in the absence of bony changes on x-ray or myelogram is reviewed. The literature suggests that cord compression particularly in the case of injury in a patient with degenerative arthritis does occur. This compression is produced dorsally by the lamina and the ligamentum flavum and ventrally by the posterior surface of the vertebral bodies. A tear in the anterior spinal ligament allowing greater hyperextension may be an associated problem. A narrowed sagittal diameter of the vertebral canal provides a clue whether hyperextension will lead to neurological deficit. A diameter of less than 13 mm. may be considered as sufficient to cause injury on hyperextension and one greater than 14 mm. as safe. Histologically the damage produced is centrally located in the cord. Five histories with neurological deficit from hyperextension injuries had sagittal diameter of 12-14 mm. are discussed by the authors. Pictures of a myelogram in a cadaver demonstrate that in a patient with a narrow sagittal diameter hyperextension produces cord compression.

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**Functional Plasticity in Cortical Speech Areas and Integration of Speech. H. Lamar Roberts.** A.M.A. Arch. Neurol. & Psychiat. **79**:275 (Mar.) 1958.

Over 600 cases of patients who had brain surgery for focal cerebral seizures were reviewed with reference to speech mechanisms. The technics by which the clinical data were obtained and evaluated to lead to the conclusions presented are not given. Six illustrative cases are presented. From these studies, it appears that the language abilities of the patients were evaluated grossly and qualitatively without the aid of standardized testing. The conclusions are of a general nature and are 1: Any limited area of the dominant hemisphere may be excised with only transient dysphasia, the remaining cortex being adequate for useful speech; 2. After excision the remaining ipsilateral cortex devoted to speech attempts to assume the whole function; 3: If in youth all speech areas are destroyed, the nondominant hemisphere subserves speech, and 4: Destruction of cortex that also interrupts transcortical connections anteriorly from the angular gyrus does not result in loss by the dominant hemisphere of the speech function. Because of this and the necessity of having an area that connects with the sensory and motor areas of both hemispheres it is proposed that there must be a subcortical area interacting with the dominant cortical speech areas in the speech mechanism.

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**Hemispherectomy in Children. Arthur M. Kaplan.** J. Pediat. **52**:476 (Apr.) 1958.

The author reviews six reports in the British and American literature covering 29 children under 16 years of age who have had hemispherectomies. He points out that there is great need for systematic reporting of objectively obtained clinical information regarding pre- and postoperative status. Although opinion is expressed, for example, on intellectual functioning in 11 cases, only three reports were based on objective measures. Methods are available for evaluating social, emotional, and intellectual functioning which are reproducible, so that comparisons could be made before and after surgery and from one group to another. Much other data should also be included, such as medication, etc. Basic

information available indicates that the status of hemiplegia improved in 35 per cent, was unchanged in 52 per cent, and worse in 13 per cent of the reported cases; emotional outbursts improved in 87 per cent, were unchanged in 13 per cent; and subjective impression of improvement of intellect in several where this information was given, with objective data of improvement in one case, no change in two, and no patient worse.

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**Attitudinal Deformities of the Lower Extremities in Small Children. Frank P. Walsh, and Sara Jane Houtz.** Phys. Therapy Rev. **38**:159 (Mar.) 1958.

A short description of the findings and treatment of five conditions in children which they term "dynamically acquired or posturally induced" is given by Walsh and Houtz. Their thesis is that children with no recognized deformity at birth appear later in infancy or childhood with deformities secondary to positioning, particularly prone sleeping with legs and feet in various positions. The descriptions of deformity and treatment are very brief and general but basically sound except for the fact that where corrections are recommended for shoes it is not pointed out that the fitting of the shoe itself, and especially the heel counter, is extremely important if the added "corrections" are to be corrective.

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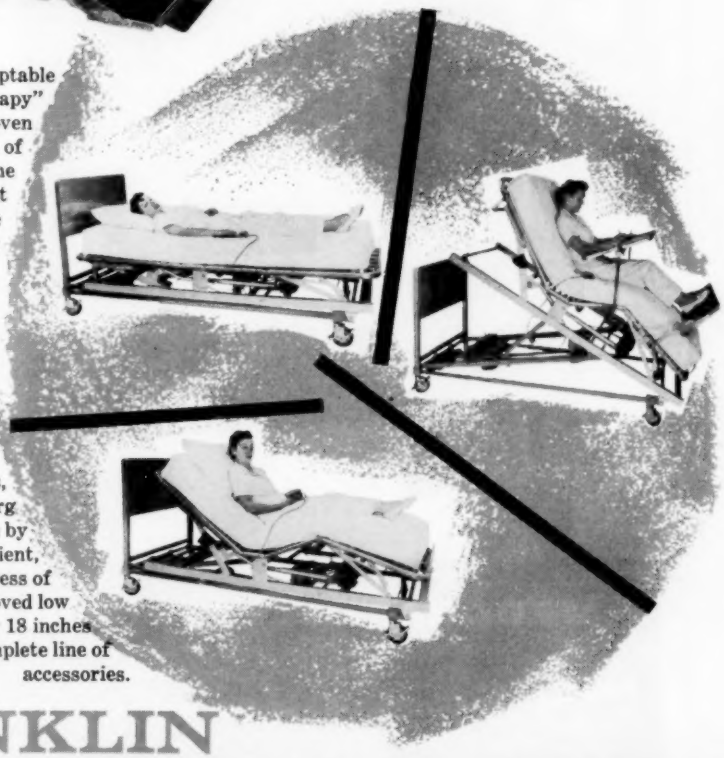

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